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The LD50 value

ITS USE AND LIMITATIONS

by **Alastair N. Worden,** *Nutritional Research Unit, Huntingdon.*

A simple index, provided that it has some measure of truth, is of considerable help in framing legislation or codes of practice: it may even prove more valuable in dealing with associated administrative or socio-economic repercussions. A majority of the population in the so-called sophisticated countries is fast accepting that the use of potentially dangerous materials is at present essential to efficient agricultural production, food distribution and the associated industries, and in this context a measure of the relative toxicity of the substances used is desired.

Widespread use is now made of the LD50[1] value which expresses, on a bodyweight basis, the dose of a substance or formulation required to kill 50 per cent. of the persons or animals or other organisms at risk. The lethal dose is that most commonly chosen, although other toxic manifestations or effects may be used and in such instances it is more correct to speak of the effective dose and, correspondingly, of the ED50. The rationale of the ED50 or LD50 is succinctly provided by Bernard DAVIDOW and Ernest C. HAGAN in the section on acute toxicity in *Procedures for the Appraisal of the Toxicity of Chemicals in Foods, Drugs and Cosmetics*, prepared by members of staff of the US Food and Drug Administration, as follows:

> By acute toxicity we mean the effect that a compound produces when given in a single dose or in multiple doses over periods of 24 hours or less. The most convenient expression of the acute toxicity of a substance is the ED50. This is the amount of the substance (usually expressed in milligrams or grams per kilogram of bodyweight) which, on the average, will affect one half of a group of animals of a certain species under specified conditions. This standard of comparison was selected because the dosage required to effect a response in 50 per cent. of the animals is more reproducible than any other dosage.
>
> Experience has shown that the ED50 will vary from species to species and with environmental conditions so that it is necessary to specify the conditions of the experiment. Species, route of administration, sex, age, weight range, and state of nutrition of test animals, as well as physical state of chemical, solvent and concentration, are the conditions usually specified . . .
>
> Because different species of animals and even various strains of the same species may differ widely in sensitivity to drugs, the LD50 should be determined on at least three species of animals, one of which should be non-rodent. An evaluation of these results will give a measure of the species variability, and thus permit the pharmacologist to estimate the toxicity of the test substance for man.
>
> If all of the LD50's are of the same order of magnitude, it is usually safe to assume a similar LD50 for man. Cyanide is a good example of a chemical which has approximately the same LD50 for most species of mammals, including man. If, however, there is a wide variation of LD50's among species of test animals, the estimation of the probable LD50 for man is much more difficult. In some cases, the estimate can be based upon man's position in the phylogenetic scale in relation to the test animals. In other cases the estimate must be based upon biochemical and metabolic similarities of man with the test animals. For example, a chemical that may produce methaemoglobinaemia as its characteristic effect can be tested in the cat or dog, known to yield this response similarly to man. Tests in monkeys, rats and rabbits, which are known to produce practically no methaemoglobinaemia in response to such chemicals as acetanilide and nitrobenzene, would obviously be of little value in estimating this particular hazard for man. Where adequate knowledge of the similarities between man and test animal is not available, it is safest to assume that man is at least as sensitive as the most sensitive species of animal tested.

Death a Good Criterion?

Death is the most definitive index of toxicity and, as such, has come to be adopted as the criterion. In many instances, however, it is unfortunate that some other effect index is not employed. There is no need to elaborate upon the reasons why death is so obviously a crude measure of assessment. More precise observations upon a particular effect would often throw much greater light upon the potential hazard of the material under test. The choice of LD50 (or of some other mortality index), rather than of an alternative notation based upon a characteristic symptom, behavioural response or lesion, is indicative of the attempt to simplify—and of the dangers of over-simplification.

A recorded LD50 value of the order of, say, 15mg/kg bodyweight is indicative of the fact that, by the route of administration and for the species and strain concerned, the material is potentially highly toxic. Without much information besides, this figure tells us little more. One must beware also of attributing to an LD50 value a degree of exactitude that it does not possess. Values obtained by similar techniques in different laboratories may vary quite considerably. One recent example was from our own laboratory where from probit analysis we estimated the oral LD50 of fluoroacetoisobutylamide for the rat to be of the order of 17.5mg/kg, whereas another group of workers recorded a value of 42mg/kg. Without much further information, a value of either 17.5 or 42mg/kg is of limited use in deciding the practical toxic hazard: both figures are indicative of high potential toxicity but not necessarily of extreme danger in the field. Moreover, at the

[1]There are several methods of calculating the LD50 value. That recommended in the Notification of Pesticides Scheme was published by W. R. THOMSON & C. S. WEIL (1952) in *Biometrica* **8**, 51; while E. C. HAGAN of the U.S. Food and Drug Administration refers to J. T. LITCHFIELD, Jn. & F. W. WILCOXON (1949), *Journal of Pharmacology and Experimental Therapeutics*, **96**, 99, and recommends that when a reasonably accurate value is called for, the numbers of animals employed should be such as to permit an estimation with a 95 per cent. confidence interval of 20 per cent. or less.

other end of the scale, a value of several hundred mg/kg does not by itself indicate freedom from risk or allow carelessness in use.

Recorded LD50 values should give a precise indication of the route and method of administration. Percutaneous toxicity may, in many instances, be of considerably greater importance than the oral, while in other cases it is the inhalation hazard which counts. Many LD50 values in the literature relate to a subcutaneous or intraperitoneal route of administration.

The introduction of more stringent regulations has led, in many other countries as in the USA, to comprehensive test procedures including, so far as acute toxicity is concerned, assessment of the LD50 on a variety of species. Nevertheless, in many instances a substance has been allotted an LD50 value on the basis of information on a single species. A figure of this kind is necessarily of limited validity and may be held to relate only to the particular strain—and perhaps age and size—of animal in the particular environmental conditions at the time, as qualified further by technique and by the proportion of material actually absorbed and transported to the site(s) of toxic action.

The position is complicated further when, as is so often the case, there is not any sharp end-point but a flattened type of dose-response curve. In our observations on fluoroacetoisobutylamide there was a fairly sharp elevation in percentage mortality above 17mg/kg bodyweight and there was 100 per cent. mortality at 30mg/kg. Even at 10mg/kg., however, there was a 20 per cent. mortality and doubtless there would have been isolated deaths at lower levels still. As discussed below, this type of result may be of particular significance, but the base LD50 value does not reveal it.

The LD50 value is used to specify not only "mammalian toxicity" but also that of non-mammalian organisms against which a pesticide may be employed. In the case of insecticides in particular there has been considerable research into the possible use of an alternative index. William O. NEGHERBON reviews this topic in his introduction to Volume III of the *Handbook of Toxicology* and quotes the views of workers who argue the case for an LD95 'as a more practical ground for comparing toxicity'. It would be beyond the scope of the present article to discuss the applicability of another index such as this to mammalian toxicity but there would appear to be certain cases at least in which it would probably prove preferable.

As already indicated, the calculated LD50 for two different compounds may be the same, but in one case a significant percentage of deaths may occur over a far wider range than in the other. DAVIDOW and HAGAN suggest that the slope of the dosage-mortality curve may be related to the human hazard. They point out that in human poisoning from diethylene glycol, which in most species has a "flat" response curve, some individuals have died from very small doses whereas others have survived relatively large doses. With gonyaulax toxin, which is occasionally found in clams and mussels and has a steep response curve, a quarter of the LD50 may however be eaten with almost no risk of fatality.

Interpretation Difficulties

These qualifications could be multiplied almost indefinitely and every laboratory engaged in toxicological work must have its examples of difficult interpretation or of unusual species response. DAVIDOW and HAGAN'S conclusion that 'generally, man is six times as sensitive as the dog and ten times as sensitive as the rat to the toxic effects of drugs'

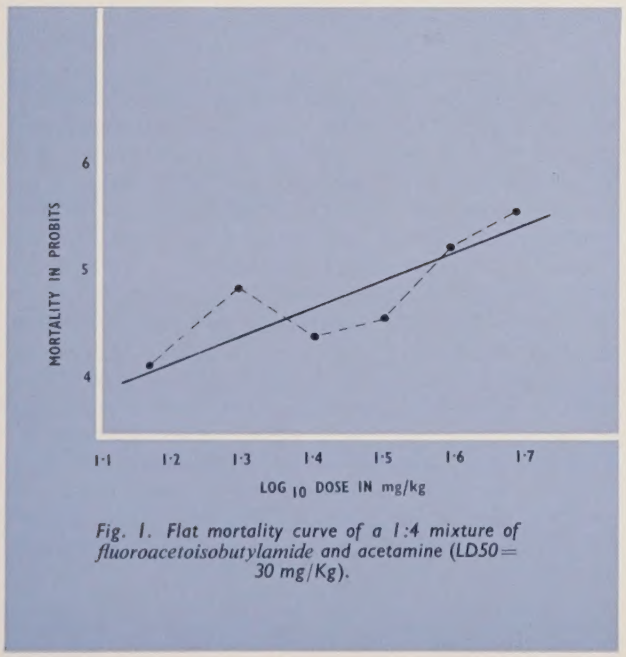


Fig. 1. Flat mortality curve of a 1:4 mixture of fluoroacetoisobutylamide and acetamine (LD50= 30 mg/Kg).

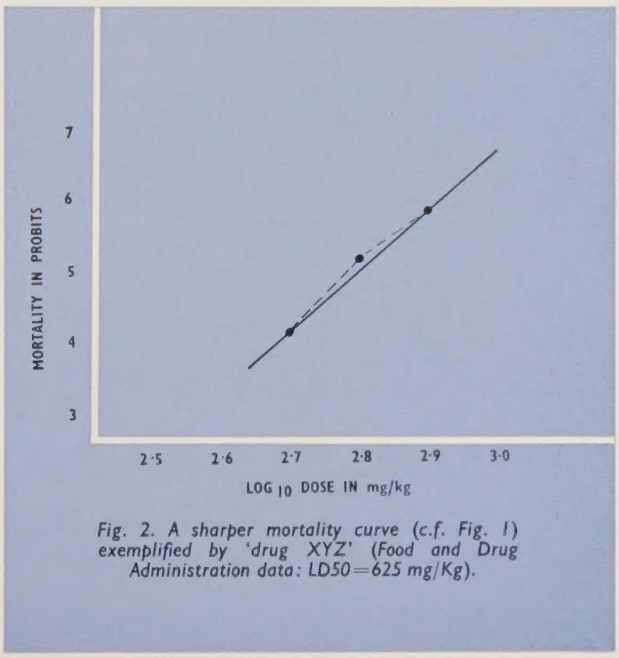


Fig. 2. A sharper mortality curve (c.f. Fig. 1) exemplified by 'drug XYZ' (Food and Drug Administration data: LD50=625 mg/Kg).

certainly does not warrant uncritical application. In the case of nitrogen trichloride or 'agene', hitherto used widely for the treatment of flour, there is now no doubt that the dog is highly susceptible and that man is very much less so. The dog is highly sensitive also to some of the drugs now employed in neurology and psychiatry and some workers believe that the rat and rabbit are better test species for monoamine oxidase inhibitors than are the dog and cat, at any rate in so far as relationship to human response is concerned.

The criterion must or should be that of the bodily mechanism(s) involved and the precise mode of action of the test substance. Only in a relatively small proportion of cases, however, is the pharmacology sufficiently well understood, and partial knowledge may prove somewhat misleading. Thus, the toxic hazard associated with organophosphorous compounds is sometimes discussed solely in terms of cholinesterase inhibition. It is true that the majority of such materials used as insecticides or otherwise in industry are significant depressors of plasma cholinesterase. There are now good examples, however, of organophosphorous compounds that are relatively poor cholinesterase inhibitors but are nevertheless highly neurotoxic, while the reverse situation has been recognised for some time.

This class of compound provides also some good examples of an apparent discrepancy between a simple LD50 value and the actual toxic hazard. With some materials with which we have been working recently, the mammalian LD50 is of a high order and even the avian one—the fowl is the most satisfactory test animal for certain aspects of organophosphorous toxicity—is many grams/kg. bodyweight. To produce acute toxicity may require such large doses as to merit the term "pharmacological flooding" of the body. Yet these compounds are capable of a chronic or cumulative effect that leads to severe and eventually irreversible changes in some of the nerve tracts.

Almost the reverse situation—a low LD50 value combined with apparent safety in use even over long periods—may be claimed for many potent pesticides, including indeed some of the organophosphorous compounds and chlorinated hydrocarbons such as endrin. This particular compound, although a potent toxic substance with a low LD50 value, has a remarkably good safety record in the field despite widespread usage during the past few years.

There seems little danger that, at the official level, too much value will be placed upon LD50 values as such without many further data. In the agreed UK scheme for the voluntary notification of pesticides detailed suggestions are made for the assessment of toxic hazard. These include information on: physico-chemical properties which would influence risks in the field; assessment of the LD50 value with studies on the apparent mode of toxic action (a highly important aspect); skin penetration and absorption; irritancy to body surface; cumulative studies in relation to user-exposures; chronic toxicity; delayed effects; potentiation by other chemicals; and a review of diagnostic and therapeutic possibilities. Should the findings of the Panel on Carcinogenic Risks in Food Additives and Pesticides lead to appropriate action in the UK, there may well be added the requirement of two-year feeding and injecting studies in appropriate instances. All this information, combined with adequate residue data and the application of sensible precautions in use, is likely to help assess—and reduce—the risks in field use.

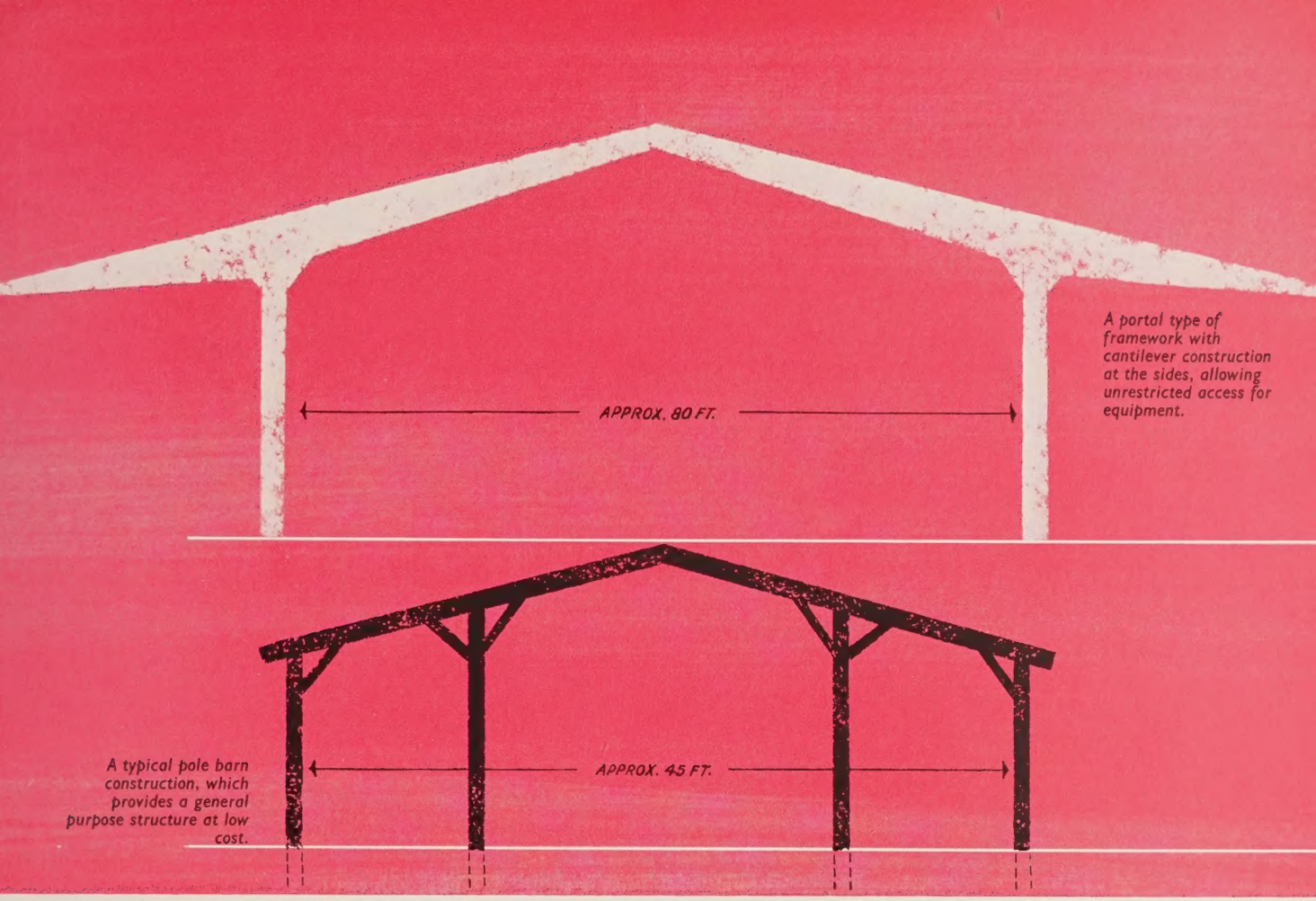
Potentiation

Potentiation is a subject that has attracted a good deal of attention during recent years, due largely to the fact that some of the organophosphorous compounds in particular are significantly more toxic when administered together than would be indicated by the sum of their respective individual toxicities. Thus in our own laboratory, in confirming that malathion may be so influenced, we found that one blend of organophosphorous compounds (which itself had an acute toxicity of the order of some grams/kg.) lowered the recorded LD50 for malathion from about 1g. down to below 20mg/kg. when given simultaneously or within a short period of time. Elaborate schemes have been suggested to cover the risk of potentiation but a matter of even greater importance is that the formulated material should always be examined and not just a laboratory preparation. Surprisingly small variations in the purity or in the formulation of a reagent may have profound repercussions upon analytical results, and the biological organism is by no means less sensitive than a laboratory chemical system to such changes.

It may be concluded that the LD50 value is a useful and convenient part of most toxicity studies and is, in many instances, a necessary or desirable preliminary to longer and more comprehensive attempts to assess the toxic hazard concerned. Provided that the value is taken within this context, and with due regard to the many other factors that influence toxicity, it may serve as a rough measure of potential risk, but that is all. A boardroom decision to reject one material because it is stated to have a value of, say, 75mg/kg. and to concentrate upon another that has a reported value of 120mg/kg. would be absurd unless supported by many further findings. It would appear to be particularly so if, for example, the determinations had been undertaken in different laboratories, in different or unsuitable species, or by a route that was not directly applicable to the principal toxic hazard.

In so far as the pesticide field is concerned, the use of materials with low LD50 values has not proved a serious user hazard, certainly in the UK. In his recent article on the applied toxicology of pesticides in the *Pharmaceutical Journal* for October 15, 1960, pp. 361-367, Dr. E. F. Edson points out that since 1946 there have been only 13 recorded fatalities[2] among users of chemical pesticides and that in the past eight years there have been about a score of authentic cases of minor temporary intoxications among farmworkers. As he has pointed out elsewhere, shotguns, fires, lightning and explosions cause as many farming fatalities in any one year as chemical pesticides have in fourteen.

[2]In the United Kingdom.—Ed.


APPROX. 80 FT.
A portal type of framework with cantilever construction at the sides, allowing unrestricted access for equipment.
APPROX. 45 FT.
A typical pole barn construction, which provides a general purpose structure at low cost.

Farm buildings for a mechanised age

by **J. N. Dominy** and **J. A. C. Gibb**

University of Reading.

Work in and around farm buildings, particularly in connection with livestock enterprises, is frequently much less efficient in its employment of labour than are other aspects of farm work, such as crop production. Work study methods of observation can frequently suggest changes in routine and minor alterations in the internal layout of buildings, and such changes may result in considerable economies. Nevertheless, the design and layout of buildings, and indeed of farmyards, is frequently found to be a limitation which prevents the adoption of effective mechanised systems of working, particularly in connection with livestock enterprises and with the storage of materials. This is, of course, merely a reflection of the fact that buildings normally have a very long life, and one cannot blame their designers of 20, 50 and 100 or more years ago for failing to provide for the mechanised practices of the 1960's.

What mechanical aspects should the farm building designer of today incorporate in his plans? The main requirements would seem to be: provision for the mechanised feeding of animals, and for dung removal; and adequate access for all present and likely future types of handling equipment, with particular reference to facilitating the storage of materials. Where bulk handling is likely to offer advantages, as in dealing with grain and milk, suitable provision must also be made.

Concentrate foods and roughages such as silage or hay may be fed together to some classes of livestock, but it is more likely that they will need separate consideration. In general, concentrates are in future likely to be stored in bulk containers, and to be moved out of storage by some type of mechanical conveyor. Other conveyors will be used to take these foods directly to the animals, and intermediate stages may include milling, mixing and perhaps pelleting. If close rationing is practised the final delivery may be through a metering device into mangers or troughs, either for individuals or for small groups of animals. Such conveyors may be located at ground level in some instances, but often it is likely to be found that for part of their

length, especially in the buildings where the food is consumed, the most convenient position will be at about ceiling level.

Silage and other roughages have different requirements and the choice of methods of handling is wider. For some applications auger or scraper conveyors may be used to fill continuous feed troughs or mangers, and in some cases concentrate foods may be added en route. These conveyors may possibly be supplied directly from tower or other storage silos. Other systems of operation may call for the use of self-unloading trailers, and here the food troughs may be arranged round the perimeter of a cattle yard, to allow replenishment from outside the yard, in a continuous pass.

Manure Disposal

Manure disposal must be considered in conjunction with mechanical feeding; at present the two main possibilities are the use of slatted floors, and—generally on larger areas—of scrapers mounted on tractors or other vehicles. In specialised circumstances, as in cowsheds, gutter-cleaners may also be used.

The main points to be considered where scrapers are concerned are adequate provision for access and manoeuvring of the tractor or vehicle, and some means of delivering the collected manure to a spreader or other disposal arrangement. Where topography allows, a sunken bay to accommodate a spreader, and a ramp to permit gravity filling, can be economical and convenient.

Slatted floors can either be placed high enough off the ground to permit tractor-and-scraper access underneath, with a consequent loss of useful building volume; or they may have limited room underneath, mechanical conveyors or slurrying systems being used for dung removal. Where sufficient water is obtainable, and especially if irrigation facilities are also available, ultimate disposal by organic irrigation may be an attractive possibility.

Storage

Building requirements for storage are difficult to forecast. Where bulk storage is concerned, adequate wall and floor strength, and access for operation and maintenance of conveyors are the prime considerations. If pallet systems of handling materials—especially bought-in materials such as seeds, fertilisers and concentrate foods—become widespread, attention will have to be given to space for carrying and stacking machines such as fork-lift trucks, or their farm equivalents. Adequate access height and storage height, and room to manoeuvre inside the building, will be of particular importance.

Farmstead Planning

It is not always easy to achieve the building conditions desirable for some of the types of mechanisation mentioned above. The traditional type of farmstead layout with its congested and haphazard building arrangement is often quite unsuitable for the effective operation of equipment, and the easy movement of materials. Unfortunately, the high cost of building is often a deterrent to the complete demolition of the entire farmstead, and replacement by new structure designed to suit modern mechanisation requirements. New building developments have often to be fitted into the existing layout, and old buildings must be adapted or converted.

Farmers are often reluctant to clear away derelict buildings, but good use can always be made of the rubble obtained from demolition for the construction and improvement of roads and paved areas, and the space made available can often help to solve a planning problem. The building grants available under the farm improvement scheme, facilities for borrowing money and the tax concessions in respect of building costs on many farms justify a much bolder approach to the question of building replacement.

The fact that it is not possible to replace the whole of an old farmstead on one single occasion should not, however, prevent the preparation of a 'master' plan of development, to be carried out in several stages if necessary. Too many farm buildings are still being erected without proper consideration of their integration with the future development of the farmstead as a whole.

Since work in and around the farmstead is for the most part a matter of movement (chiefly of materials, and to a lesser extent, of livestock), the following considerations in planning or improving farmstead layouts must be regarded as fundamental:

(1) Buildings should be arranged compactly, in order to reduce travel distances, but consideration should also be given to the space required for the operation of mechanical equipment, and for future building extensions;

(2) Use should be made of varying site levels in order to facilitate the handling of goods and materials on to and off lorries or trucks;

(3) Material should be stored in the position where it will be 'used' in order to avoid double handling;

(4) The movement of materials should be downhill rather than uphill;

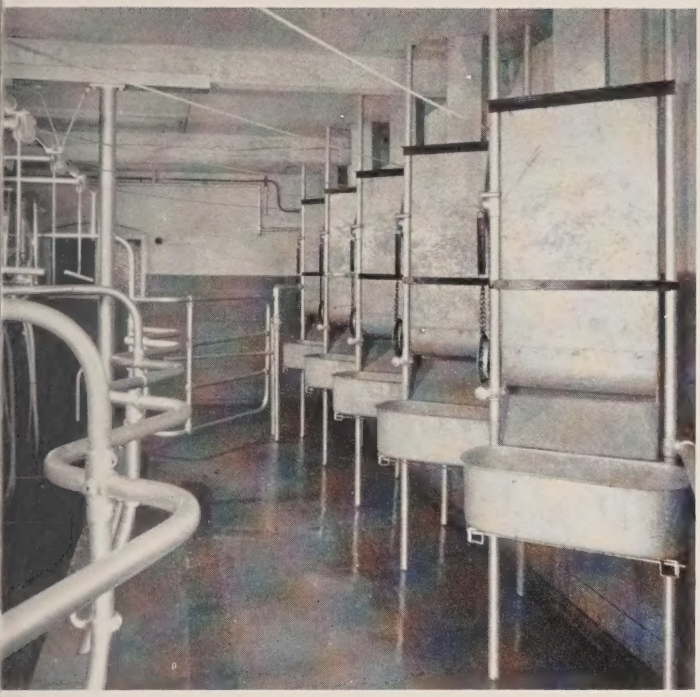
(5) Provision should be made for circular travel to avoid back-tracking;

(6) Hard, level roadways and passages—preferably of concrete—should be provided to facilitate the movement of trucks and trollies.

Developments in Farm Building Design

Yard and parlour systems for dairy livestock. The introduction of the milking machine in the 1930's led to the provision of the milking parlour, which in its turn encouraged the development of yarding systems. For any dairy herd exceeding 10-12 in number, the yard and parlour system has many advantages, and is very suitable for mechanisation. The attention which has been given, particularly at the National Institute for Research in Dairying, to the design of milking parlours and equipment has solved many of the building design problems.

For ease and speed in working, a two-level arrangement, with the cows standing approximately 30in. above the milking machine operator is now becoming well established. The storage of concentrate foods in a loft above the



A herringbone milking parlour, with remote-controlled individual feeding meters (Gascoignes [Reading] Ltd.).

A self-unloading trailer delivering food to a trough forming the boundary of a cattle yard.
(Photo: *Farmers Weekly*)

A two-storey windowless poultry laying house. Droppings are conveyed to the manure spreader shown.
(Photo: *Poultry World*)

parlour will permit automatic replenishment of the cows' troughs by gravity. For the larger herds the herringbone type of parlour, originating in New Zealand, provides a further opportunity for work simplification. The cows are brought into the parlour, milked, and released in batches, alternately on each side of a central pit.

Slatted Floors. Shortage and high cost of the normal straw bedding used for cattle in covered yards has led to the use of alternative material such as sawdust or peatmoss, and also to the practice of accommodating the animals on silage stacks suitably protected by chalk. More recently, slatted floors of timber, concrete and steel are increasingly being used to eliminate altogether the necessity for bedding material. At the same time, the use of slatted floors can reduce the space requirements per animal by some 50 per cent. The problem of dung removal from beneath the floor has already been noted.

Pigs and Poultry. Slatted floors are also being used in piggeries, not with the object of saving bedding material, but as a means of reducing the labour of dung removal. The slatted floor in this case is restricted to the area used by the pigs for dunging.

Mechanical systems of feeding can also be incorporated easily into the modern type of piggery.

Temperature has a considerable effect upon growth and food conversion rates in pigs. To achieve uniformity in temperature, yard housing systems are not really satisfactory for the fattening pig, and a specialised building, highly insulated and mechanically ventilated, is desirable.

The environmental requirements of poultry are somewhat similar to those of pigs, except that the length of lighting period must be closely controlled. One new development is the window-less house, with controlled ventilation and lighting and efficient insulation, and with a floor of wire mesh or timber slats. The birds are fed automatically, and in some cases egg collection and droppings removal are also automatic.

Building Materials

Developments in building materials and methods of construction have affected farm building design in a number of ways. The increasing use of prestressed precast concrete for the structural members of a building framework, and also for beams (used for both slatted and other types of floors) has enabled reductions to be made in the size and weight of the members, thus leading to easier handling and greater unsupported spans. Various types of precast lightweight concrete slabs and blocks have improved insulation properties, and can be assembled rapidly.

Roof pitches for the wider buildings have been reduced and, by the use of cantilever construction, the supporting uprights along the sides of a lean-to can be eliminated, thus giving complete freedom of access for implements and equipment. Steel frames and timber structures are once again in strong competition with precast concrete, as the structural frame for farm buildings. The portal type of outline to give freedom from roof obstructions is being increasingly used in all three materials. For timber roofs several thicknesses of plywood are glued together to form laminated structural members, and metal jointing rings are increasingly used with small-sized timber sections to replace the large and heavy beams of traditional construction. To avoid the difficulty of repainting the top of steel angle roof purlins, pressure-treated preserved timber beams are used instead of steel; repainting of the steelwork then becomes a relatively simple matter, especially if a large single-section portal frame has been used.

Resin-bonded plywood can now be employed for external roof sheeting if protected by a bituminous paint or felt. Other relatively new cladding materials include aluminium alloy sheeting (now obtainable in lengths of up to 30ft.), and rendered wood-wool slabs.

For controlled-environment structures for pigs and poultry a wide range of insulating material is now available, including compressed strawboard, foamed plastics, mineral wool and polystyrene.

Practically all these new materials are light in weight but durable, and are well suited to systems of prefabrication which must be increasingly applied in order to produce reasonably cheap farm buildings.

Future Trends

There appear to be two main lines of farm building development. Rapid changes in farming methods and systems are certain to continue and there is clearly need for adaptability and flexibility of use in any permanent structure. Buildings for cattle and for crop, grain and implement storage may thus be provided by using a general-purpose dutch-barn type of structure to provide an 'umbrella' cover, within which alterations can be made according to changing farming requirements. Loose housing systems fit well into this type of building. Such general-purpose buildings do not so easily meet the requirements of pig and poultry enterprises, and here the development of specialised buildings appears to be fully justified.

The alternative to a permanent general-purpose building is a cheap and temporary structure which will serve for a few years, and which can then be scrapped and replaced by a new building more suited to the altered conditions. Temporary structures of really low initial cost must be able to be built by farm labour. Timber structures of the pole barn type can provide reasonable shelter for cattle, implements and crops, and lightweight, easily handled materials, such as timber, aluminium, bituminous felt and wire netting, are convenient for farm labour to use. Climatic and site conditions, and the particular management factors concerned must, however, dictate the final decision as to the use of temporary structures, or alternatively, the provision of buildings of a more durable character—designed wherever possible to give flexibility in use.

Farm machinery and equipment is unlikely to become smaller in overall dimensions than at present, and the main provisions in new buildings should include access openings of thoroughly adequate height and width. Since gravity continues to be the cheapest method of moving materials, the use of two-storey buildings, allied to adequate upper-floor carrying capacity, might be further investigated.

The training of nematologists

by **B. G. Peters,** Ph.D., *Imperial College of Science and Technology.*

Because plant nematodes tend to be insidious rather than devastating in crop damage, farmers may live with them for generations without realising that their crop yields could be greatly improved by attention to pests, the mere presence of which is not even suspected. Many areas of the world where nematodes are almost certainly responsible for large-scale crop losses have not so far been surveyed for nematodes—because of the lack, outside the USA, of trained nematologists.

In the following article, Professor Peters points out that, at any rate until recently, a vicious circle has existed in nematology: 'no jobs because no trained nematologists', and 'no incentive to train them because no jobs'. Now that courses have been introduced in the UK and the Netherlands, there is hope that this circle will be broken: while opportunities for trained nematologists may remain fairly limited—though by no means non-existent—in Western Europe, the scope in tropical and subtropical countries is certainly enormous.

In 1914, N. A. Cobb, who has been named the father of nematology, vividly called attention to the ubiquity of nematodes, the free-living species of which are to be found in almost every conceivable habitat except the wholly arid. He it was, too, who introduced in America the use of terms like 'nemic', 'nematology', and 'nematicide'; this usage he stoutly defended in an article characteristically entitled 'The English word "Nema" '.

Some of the nematodes parasitic in man and in his domesticated animals have been known for centuries. But the free-living and plant-parasitic species have become known mostly within the last 100 years, and especially since the pioneer work of Cobb. Whereas most of the parasites of animals are easily visible to the naked eye, the free-living and plant-parasitic species are small to microscopic, and often transparent also. Again, the Nematoda form a closely-knit group of animals in much the same way, taxonomically, that the birds do. But whilst birds can be differentiated by clearly visible external characters, the nematodes call for a close study of internal characters, some of them visible only under the highest powers of the optical microscope, critically used.

Thus, the facts that these nematodes both are very small and are differentiated by means of fine detail, combine to make their study dependent on good microscopy. This was not available until after 1830: hence the late development of the subject. Hence also the aversion felt by many zoologists for this group of animals: they are difficult to handle and difficult to classify. There are technical problems in extracting a slender transparent worm 1mm. long from a mass of plant tissue or from the soil, processing it without damage or distortion for microscopic examination, and studying it under an oil-immersion lens by means of highly efficient illumination. And supposing all these problems to have been overcome so that the worm's anatomy is clearly visible, there remain difficulties of taxonomic interpretation.

Not every biologist wants to be a taxonomic specialist, of course; nevertheless, the first essential is to recognise the worm being dealt with.

Academically, nematology is concerned with nematodes of all kinds, and there is much to be said in favour of a wide acquaintance with the group as a whole. But in practice the nematode parasites of animals tend to become the concern of medical and veterinary parasitologists, for obvious reasons. When the nematode parasites of plants have received any attention at all, in the past, it has been at the hands of entomologists in some countries and plant pathologists in others. There are points in favour of each

alternative. But the best possible arrangement, to have them dealt with by trained nematologists, has seldom been adopted, for the simple reason that there have been no trained nematologists available, and almost nowhere to train them.

It is, in my view, impossible to include in the undergraduate syllabus a detailed study of the nematodes, with adequate technical practice, without either overloading the syllabus or throwing it seriously out of balance. Even at Imperial College, where parasitology is a third-year specialism alternative to entomology, and where more time is devoted to the special subject than at most British universities, the plant nematodes are sketchily dealt with in four lectures. It follows that, if nematology is to be adequately taught, it must be at the post-graduate level.

Hitherto in the United Kingdom this has been by means of research grants tenable in a university department of zoology or at one of the very few research stations or agricultural colleges specialising in the subject. The student works on a research problem for three years and usually submits a thesis for a Ph.D. degree. He becomes well-acquainted with, perhaps, the one species of nematode on which his research is centred. His knowledge of the subject as a whole is picked up casually and piecemeal if at all.

This is one respect, I submit, in which the American Ph.D. syllabus, with its course work of lectures and practicals, has an advantage: it can give an adequate background.

For some years courses in plant nematology have been available at several American centres (e.g., Berkeley, Cornell, Wisconsin); but outside the USA, to the best of my knowledge, there had been no regular formal instruction—except at Wageningen Agricultural University in Holland—until the institution of a one-year postgraduate course at the Imperial College Field Station in 1958.

The new nematology laboratory at Imperial College Field Station nears completion (seen from the back).

The author with his assistant, Dr. N. G. Hague, and the students who attended a recent nematology course at the Imperial College of Science and Technology. Left to right: *J. L. Jambrina Alonso (Spain); J. A. Shepherd (Rhodesia); Dr. Hague; Professor Peters; P. E. Udeaja (Nigeria); J. S. Gill (India).*

This course falls into three interdependent parts: nematology proper, control methods, and experimentation. It involves lectures, laboratory work, visits to selected field outbreaks of nematode diseases, visits to research stations, and (above all) a small individual research problem in which the student can seek to apply the knowledge acquired in the course work. The year's work, if satisfactory, can lead to a Diploma of Membership of Imperial College (DIC). A slightly more detailed description of this course will serve to illustrate my views on the training of nematologists.

Essential Nematology

The purely nematological section of the course deals with the structure and anatomy of a generalised nematode in some detail, and then passes on to review briefly all the nematode Orders in turn. Next, some consideration is given to the many free-livers from soil. The plant nematologist needs to know the free soil nematodes because there are many possibilities of confusion. Thus, most plant parasites belong to a recognisable Order, *Tylenchida*, but not all tylenchids are parasites: some are free-living. On the other hand, once a root has been damaged, by parasitic nematodes or in other ways, non-parasitic nematodes may enter the rotting tissues to feed upon bacteria or other micro-organisms. Also, the true parasites vary widely in their behaviour towards the host: some are sessile, some are motile within the plant tissues, and some are freely migratory from root to root through the soil. To compli-

cate matters, many nematodes parasitic in animals at one stage in the life-cycle have other stages free-living in soil.

The plant-parasitic nematodes are dealt with in greater detail, covering not only morphology and taxonomy, but also a study of the life-cycle, of biological peculiarities, and of the relationship of parasite and host. Many species are maintained alive at the field station in outdoor plots or in heated beds in the greenhouse. If our own commoner parasites tend to be scarce in the tropics (e.g., *Heterodera*, *Ditylenchus*), their place is taken by other and more harmful species which fail to grow in our cold soils without artificial heat.

Earlier, some stress has been laid on the technical difficulties of the subject. These are dealt with in extensive periods of practical work in the laboratory, the practical aspects of nematology being of greater importance in the early stages than the theoretical.

Some attention is also given to the nematode parasites and associates of insects, though there is not time to do justice to this interesting and much-neglected field.

Control Methods

The second main subdivision of the one-year course is concerned with chemical and physical methods of control. The intention here is not to dispense remedies but to study the fundamental principles underlying their formulation and use. The syllabus embraces chamber fumigation of plant materials, fumigation of field soils, and the use of foliar sprays. The student is encouraged to face the difficulties encountered in moving from a neat laboratory experiment to a pot experiment in the greenhouse and from there to an experiment in the field. At Imperial College there is a long tradition of research into the fundamental principles of fumigation with insecticides, and it is most satisfactory that this part of the course should be in such expert hands.

Experimentation

The third main subdivision has been called 'experimentation' as being a more informative word than 'statistics'. The average zoology graduate is sadly deficient in an understanding of how to design and analyse a simple experiment, of how to draw valid inferences from his results by using 'the calculus of probability'. This is one more subject which requires postgraduate rather than undergraduate attention. It is also one from which the non-mathematician profits very little unless the theoretical instruction is supported by copious practical work. This section also deals with bioassay methods of evaluating nematicidal tests, and touches upon the interesting but difficult field of biometry.

The three subjects are so taught as to display their interrelations, and the students are given joint exercises in nematicidal treatment which draw upon the knowledge and practical experience they have gained in all three fields. In addition, each student has an individual small research problem allocated to him in the light of his special interests.

The course is open to Honours graduates (or equivalent) in zoology or botany, preferably in either case with the other subject as a subsidiary. In its first three years it has been restricted to a maximum of four students by reason of available space. That room was found at all was only at the expense of the entomologists previously in possession, and by severely restricting the numbers of higher degree students.

Equipment has been a further problem. This is a subject in which each student requires a good dissecting microscope, the best high-powered microscope that can be afforded, and a useful calculating machine, in addition to communal laboratory and glasshouse equipment. It requires something like £500 to capitalise each student-place, apart from recurrent expenditure and overheads.

New Laboratory

An entirely new situation is now arising at the field station. With the help of a grant from Shell International Chemical Company a new building of adequate size is at present nearing completion. It will be adequately equipped. The ground floor will be largely given over to the one-year postgraduate course in nematology, while the first floor will house higher degree students in this and other branches of parasitology. The new building will accommodate a maximum of 12 students at a time in the one-year course.

At present, jobs are few and far between, because hitherto there has existed a vicious circle: no jobs because no trained nematologists; no incentive to train them because no jobs. If the new course can establish and maintain a high reputation there will be a gradual break from the vicious circle. The fact that the eight students in the first two years of the course were so widely dispersed is a good omen. They came from England, New Zealand, Iran, the Philippines, Nigeria, Southern Rhodesia, India and Spain.

University teaching cannot flourish in a vacuum. It is healthiest when it is most closely in touch with active research. The new building has space for both the present staff and some half-dozen higher-degree students. Present lines of research cover such matters as the rate at which given parasitic populations build up in time and spread spatially, under varying conditions. To the question how, after a nematicidal treatment, its lethal effect is to be gauged, there is at present no clear and unambiguous answer: this field is being explored. An important and attractive area of enquiry concerns the physiology of the parasite and its relation with that of the host plants, or animals. Entry into this area is difficult with small organisms, but among many possible research tools are the radio-tracer techniques: one room in the new building is being equipped specially for work of this type. In these ways we hope that training and research in nematology will stimulate each other, by a process akin more to symbiosis than to parasitism.

If this article seems largely to have degenerated into a description of a postgraduate course in existence at Imperial College, the reason can be given. I was invited to state my views on the training of nematologists. My views are largely embodied in the Imperial College course and are most clearly explained by describing it.

Soil research in New Zealand

AGRICULTURAL RESEARCH STATIONS—5. TAITA EXPERIMENTAL STATION

by **K. E. Lee,** D.Sc., *Officer-in-Charge, Soil Biology Division, New Zealand Soil Bureau.*

Taita Experimental Station is a centre of soil research which is being developed as the headquarters of the New Zealand Soil Bureau. Located on the eastern side of the Hutt river valley, it comprises an area of six acres, for buildings, and a further 200 acres of hilly land, consisting of several small stream catchments, for experimental work.

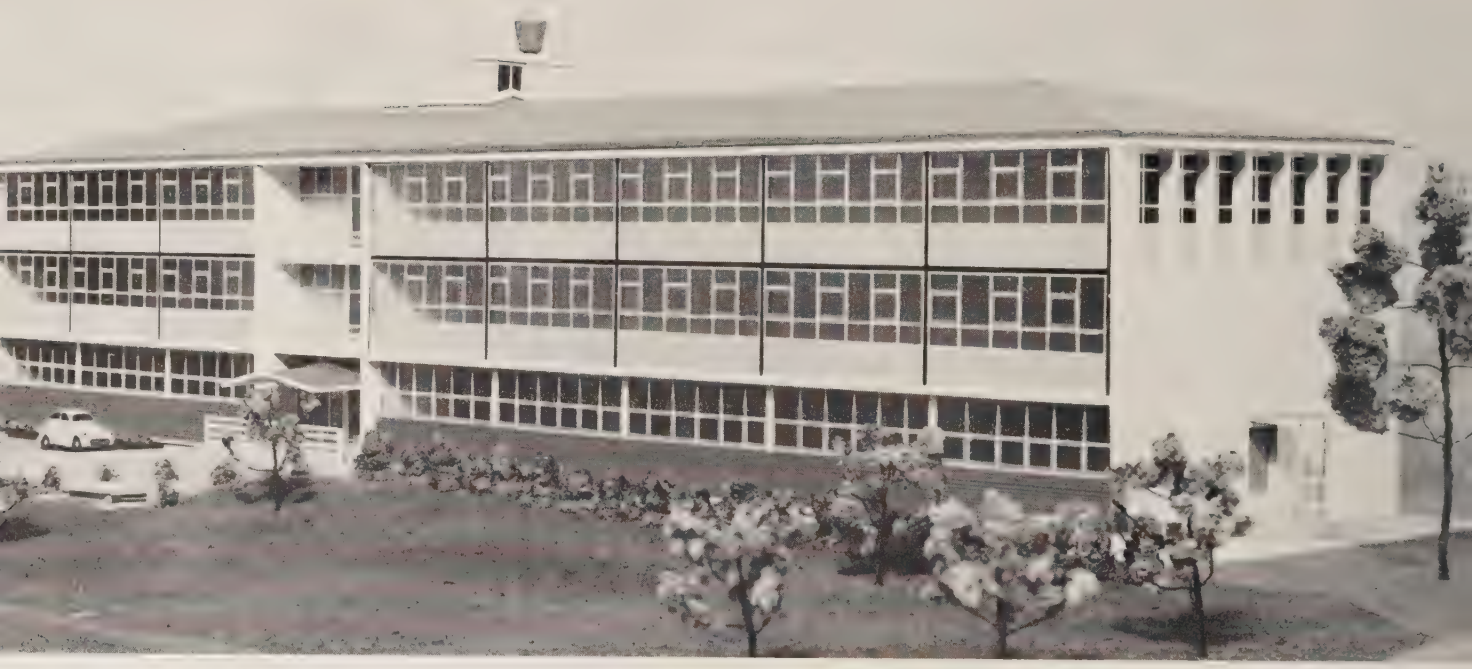
Findings from the catchment experiments, outlined below, should have wide application in New Zealand where, as in other countries, an expanding population necessitates finding ways of using land to its best advantage. The catchments at Taita represent the principal land use patterns of New Zealand and present an opportunity to relate soil science to practical land use problems; they should also yield information on the chemical, physical and biological processes involved in soil formation.

The history of Taita Experimental Station is short, but the lines along which it has developed are unusual and should in the years ahead help to solve some of the basic problems of soil science. Negotiations for the establishment of the station began in April, 1948, and continued until June, 1951, when an area of six acres of government-owned land was vested in the Soil Bureau. These six acres comprised the lower slopes and bottomland of a small stream valley that opens into the Hutt river valley, and were set aside for building purposes. Since 1951, the station has acquired more of the adjacent hilly land and grown to a total area of about 200 acres. Temporary buildings at present house the Director of the Bureau and some members of the staff. A permanent building to house all the laboratory staff is being constructed.

In its original concept the station was intended as a site for a permanent Soil Bureau building, closer to the soil and to soil problems than the disreputable old building in the heart of Wellington's commercial district that has housed the Bureau since 1940. But from this rather small beginning there has come a novel approach to some of the problems of soil science.

In soil science, as in many other scientific studies, there is an ever-increasing tendency for individual workers to

Taita Experimental Station from the air. The native catchment is marked A *and the exotic catchment,* B. *The grass catchments are Nos. 4, 5, 6 and 7.*
(Photo: New Zealand Department of Lands and Survey.)



A model of the new laboratory building being put up for the Soil Bureau at Taita. (Photo: New Zealand Ministry of Works.)

specialise and confine their efforts to narrower lines. This trend is inescapable, but it has the disadvantage that it leads to excessive fragmentation of the subject and consequently to difficulties of communication of ideas and correlation of findings. Soil Bureau personnel are drawn from a wide range of scientific disciplines, including geology, inorganic and organic chemistry, physical chemistry, biochemistry, zoology, botany, microbiology, agricultural science and engineering. Much information has been accumulated since 1930, when the Soil Bureau was founded, and it was felt that the time had come for some attempt to integrate the work of the various specialists.

The Taita Experimental Station offered an ideal situation for such an integrating project. It is sited on moderately weathered yellow-brown earths of rather low fertility, with a high proportion of hilly and moderately steep land, conditions common to large areas of hilly land in southern North Island and northern South Island districts. So the results of experiments carried out on the soils at Taita are applicable over wide areas of land that is at present of marginal economic value, but could be utilised if ways could be found to farm it more efficiently.

Three Catchments

The property is made up of a number of small, fairly steep stream catchments, all opening into the Hutt river valley. A stream catchment may be regarded as a natural unit of landscape, and results of experiments may reasonably be applied to larger catchments, and so to landscape in general. So six small stream catchments were set aside for investigation. One, of 38 acres, adjacent to the buildings, has been left almost undisturbed. The second, of 10 acres, has been cleared and planted in exotic conifers. The remaining four, ranging from about 10 to 40 acres, are being cleared and will be planted in permanent pasture. For convenience, the three types of catchment are known respectively as the native catchment, the exotic catchment and the grass catchments.

Up to the time of first settlement by Europeans (about 1852), the present experimental station area was heavily forested, with hard beech, *Nothofagus truncata*, dominant. Botanical survey work indicates that by the mid-1860's the forest had been destroyed by burning and the hills had been invaded by manuka, *Leptospermum scoparium*, scrub, and bracken, *Pteridium aquilinum*, var. *esculentum*, with some regeneration of hard beech. Successive fires in the ensuing years have resulted in the spread of manuka, gorse, *Ulex europaeus*, and some pines over most of the hills, with beech trees surviving only in damp situations.

Native Catchment

Work began in the native catchment in 1955, and is still in progress. The preliminary aim is to compile a balance sheet of the elements entering and leaving the catchment. Differences between incoming and outgoing elements must result from processes (largely soil processes) within the catchment. Should the balance sheet not agree with estimates based on present soil knowledge, it should give a lead to where knowledge is lacking and further work would be worth while. Early work centred around the design and construction of a suitable meter for accurately measuring stream flow, a difficult problem in itself when variations in flow may be of the order of a thousand to one. A climatological station was established and experiments were carried out to determine rainfall variation in relation to topography and aspect. A detailed botanical survey of the native catchment was published in 1957, and detailed soil and geological surveys are in hand.

Chemical analyses of samples of rain water are carried out regularly. Continuous records of the flow in the stream draining the catchment are compiled and studied in relation to records from a constant recording rain gauge.

A dam and flow meter for measuring stream discharge, in the native catchment.

From stream flow and rainfall records Dr. P. Whittle, formerly of the Applied Mathematics Laboratory, New Zealand DSIR, has had some success in constructing a mathematical model of the stream discharge, which might be applied to other catchments. Such a model could be of great use to engineers working in the field of flood control. It is possible to distinguish three components of stream flow—surface run-off, sub-surface run-off (i.e., water that percolates down through the soil and is discharged from transient water tables due to compact soil horizons) and water discharged from the permanent water table. It should be possible, as further results come forward, to relate the quantities of dissolved and suspended materials in the stream water to the three separate components of flow, and thus to assess their relative importance in soil development and degradation.

As a check on the efficiency of rainfall and run-off measurements it was suggested by Dr. E. W. Russell, during a visit to New Zealand in 1955, that measurements might be made of the chloride content of rain and stream water. Chloride is derived mainly from the sea, and is deposited in solution in rain water. About 120-140lb. per acre per year falls at Taita. Its retention by the soil is negligible, so measurements of the amount of chloride in rainfall and run-off over a long period would provide a check on the accuracy of hydrological data. Chloride in rain water is estimated by chemical analysis, and for the stream water an instrument giving a constant record of chloride concentration has been installed.

Exotic and Grass Catchments

The exotic catchment has been cleared and planted under the supervision of the New Zealand Forest Service as a miniature forest of exotic trees, with species selected to suit the topographical and soil conditions available in the catchment. Western red cedar, *Thuja plicata*, has been planted on the valley bottom and lower hill slopes, Douglas fir, *Pseudotsuga taxifolia*, on the steep slopes, and Corsican pine, *Pinus laricio*, on the ridge tops and adjacent easier slopes.

The grass catchments are being cleared and on them will be established typical New Zealand pastures (rye grass and white clover dominant).

Measurements of stream flow and mineral balance paralleling those in the native catchment will be carried out in the exotic and grass catchments.

Laboratory and Field Investigations

The temporary buildings erected on the station were occupied late in 1952 by the staff of the Soil Biology Division, two agricultural soil physicists, and the Wellington district pedologist. The remainder of Soil Bureau staff continued to work in Wellington. The director of the Soil Bureau, Mr. N. H. Taylor, moved to Taita in 1957, while the district pedologist returned to Wellington.

The Biology Division of the Soil Bureau was established in 1948, to investigate the nature of living organisms in New Zealand soils and their contribution to the processes of soil genesis and development. In 1952, the professional staff of the division consisted of Dr. R. H. Thornton, working on soil fungi, Dr. J. D. Stout, working on soil protozoa, and Dr. K. E. Lee, working on New Zealand earthworms. Dr. Thornton was officer-in-charge of the division. Subsequently, Dr. D. J. Ross, a biochemist, Dr. M. E. di Menna, an authority on yeasts, and Dr. T. M. Morrison, a plant physiologist, joined the staff.

From 1953 to 1957 much of the microbiological and biochemical work was concentrated on a study of the micro-organisms of some soils under New Zealand native tussock grasslands, and the changes that take place when such land is sown in exotic pasture grasses. This work was followed by a study of microbiological changes in the soil

induced by the clearing of native forest and its planting in exotic pasture grasses, and then extended to include a study of micro-organisms living on the leaves of pasture grasses. The investigations were aimed at accumulating background information on New Zealand soils, with no specific economic objective in view.

It was found that pasture leaves and the soil immediately beneath the pasture each had a distinct microflora. The soil microflora remains fairly constant, even through a change in vegetation from forest to pasture. Highest populations are attained in spring and summer and lowest populations in winter. It was noted that very large populations of individual species were found on pasture leaves for short periods when conditions were specially favourable. A red yeast, found on the leaves of rye grass, at times accounted for 1 per cent. of the weight of the leaves.

Facial Eczema

For many years, New Zealand farmers have been troubled by outbreaks of facial eczema in sheep, a disease that impairs the functioning of the liver, producing photosensitivity which may result in facial lesions, and causes heavy losses among sheep and occasionally cattle and horses. Outbreaks of the disease are sporadic, but it had been demonstrated that they most frequently occur in early autumn where showers of light, warm rain follow a long period of drought. It had been shown by Agriculture Department research workers that facial eczema was caused by some extremely toxic material, apparently associated with rye grass, and produced in significantly damaging quantities mainly in conditions favouring rapid grass growth. It was long considered that the toxic material was in the grass, and research had been directed at isolating and identifying the toxin.

The seasonal occurrence and sporadic distribution of facial eczema, taken in conjunction with the discovery that very large fluctuations in microbial populations on grass leaves and in soil may be associated with similar weather conditions to those during outbreaks of the disease, indicated a possible microbial origin for the toxin. Field observations and laboratory work were therefore undertaken by Soil Bureau microbiologists, in collaboration with Agriculture Department workers, starting in 1957. As a result, it was demonstrated that a fungus, *Pithomyces chartarum* (sometimes referred to as *Sporidesmium bakeri*), grew vigorously on debris from dead pasture plants on the soil surface, when weather conditions were favourable for facial eczema and when chemical tests developed by Agriculture Department workers showed that the facial eczema toxin was probably present. Dr. Thornton and Dr. Ross isolated and grew various strains of *Pithomyces chartarum*, collected from pastures with a history of facial eczema outbreaks. It was found that a culture of one of the strains, when fed to test animals (guinea-pigs and lambs), produced liver damage typical of facial eczema.

This discovery gave a much needed boost to facial eczema research. For the first time it was possible to produce, in the laboratory, material containing facial eczema toxin. A large-scale attack on many aspects of the disease was quickly organised. This involved mainly Agriculture Department staff, assisted by workers from the Soil Bureau and other divisions of DSIR. Chemical methods for extracting the toxin were evolved and by late 1959 a substance, sporidesmin, believed to be the toxin, was isolated.

Much work is still in progress on *Pithomyces chartarum* and other aspects of facial eczema. Dr. Thornton left the Soil Bureau early in 1960 to work in industry, but Dr. Ross is continuing biochemical work on the nutritional requirements of the fungus. A cure for facial eczema has not yet been found, but the discovery of the association of *Pithomyces chartarum* with the disease brings the possibility of prevention or cure closer to realisation. [The research which led to the discovery of the association of *P. chartarum* with facial eczema will be the subject of an article in a future issue of *Span*—Ed.]

The chain of events in the Soil Biology Division that led to its participation in facial eczema research illustrates the value of research on fundamental problems. There could have been no objective further from the minds of those who began working on the microbiology of grassland soils in 1953 than the discovery of an organism causing facial eczema.

Dr. Morrison, who worked at Taita for only two years, made a study of phosphorus uptake through the roots of pine seedlings, with and without mycorrhizae[1]. He used radioactive phosphorus as a tracer and showed that phosphorus uptake by the plant was enhanced by the presence of mycorrhizae.

Dr. Stout worked for some years on protozoa in New Zealand soils and has in preparation a bulletin summarising the results of this work. More recently he has worked on soil bacteria, and has undertaken studies of the microflora of the leaves of pasture grasses. With Dr. di Menna, whose interest is in the free-living yeasts of soils and pasture leaves, he has moved on to a study of microbial physiology and ecology in the interesting and important field where the soil, the pasture plant and the animal come together. No one would be prepared to predict what might come from their investigations.

Dr. Lee began a study of New Zealand earthworms in 1949, resulting in 1959 in the publication of a monograph covering the description and classification of the 192 New Zealand species, their distribution and ecology, and relationships between their biology and the characteristics of New Zealand soils. Work on soil animals is now being extended to include a wider range of soil inhabitants and their contributions to soil processes.

With the completion of the new building, scheduled for 1962, all the laboratory staff of the Soil Bureau will be grouped at Taita. There will then be greater opportunity for the development of an integrated research programme based on the Bureau's nation-wide programme of soil surveys and on the results of the catchment projects at Taita.

[1]Mycorrhizae are fungi that are closely associated with the roots of some plants and apparently contribute to the absorption of nutrients by the plants.

RICE GROWING IN AUSTRALIA'S NORTHERN TERRITORY

by **E. C. B. Langfield** *and* **J. D. Moir,** *Coastal Plains Research Station, Darwin.*

Rice is now being grown commercially on the sub-coastal plains of the Northern Territory of Australia. Like all new agricultural developments this venture has its problems. These are being tackled at the Coastal Plains Research Station at Humpty Doo, some 45 miles east of Darwin. In the following article, two research workers from the station report on their work and discuss the scope for improvement in this project.

The sub-coastal plains of the Northern Territory are well-defined areas totalling some 2,650 square miles of country. From the narrow coastal littoral they extend along the major rivers for up to 60 miles. In the northern section these include the Adelaide, Mary, Margaret, Wildman, West, South and East Alligator Rivers, and in the western section the Finness and Daly Rivers.

Darwin is situated on the northern coastline between each of these sections. As the western section is largely inaccessible during the wet season and large areas are aboriginal reserves, development seems unlikely for some time. Rice development to date has been confined to the plains on the west side of the Adelaide River where land access to Darwin is possible throughout the wet season.

These plains are low lying and flat, traversed by meandering tidal streams which in parts are replaced by distributaries and flat channels. The soils of this northern section are estuarine plain clays which are plastic when wet, compact and cracked when dry. The plains are rain flooded for several months of each year. The vegetation consists mainly of swamp grasses and reeds, with patches of tall Melaleuca forests in low areas.

The region is monsoonal, with definite wet and dry seasons with fairly constant temperatures. The bulk of the rainfall occurs between November and April, and rain falls rarely between May and September. The total yearly average rainfall is approximately 60in. and records at Darwin show that even in the driest years the yearly rainfall does not fall below 40in. while in the wettest the rainfall reaches nearly 80in. per year.

November, with a mean temperature of 85.9°F. is the hottest month, and July the coolest, with a mean

temperature of 77.4°F. July is the driest month and February the most humid.

In 1884, five acres of rice at Darwin produced eight tons of uncleaned rice. In 1886, Chinese growers on the Margaret River produced a ton of rice from 30lb. of seed. A yield of 64 bushels per acre is recorded from the Fannie Bay area of Darwin in 1909.

No major development in rice production took place in the area until 1952, when the Agricultural Department of the Northern Territory Administration began research investigations at Beatrice Hill, 40 miles south-east of Darwin. This research work was taken over by the CSIRO (Commonwealth Scientific and Industrial Research Organisation) at the beginning of the 1959-60 wet season, with the foundation of the Coastal Plains Research Station at Middle Point, Humpty Doo. In 1954, a commercial rice-growing company, Territory Rice, Ltd., started seed bulking at Humpty Doo. This company, backed by American and Australian capital, entered into an agreement in 1956 with the Department of Territories to develop progressively extensive areas of the sub-coastal plains. The company is at present farming 5,500 acres of rice.

Crop Establishment and Harvesting

Seedling establishment is the major problem at the present time. Whereas most major rice-growing centres have irrigation water available for crop establishment, no such water exists at Humpty Doo. The large acreage sown with rice is dependent upon an erratic early rainfall which may begin any time between early October and mid-January. As the soil is easily saturated and is difficult to work when wet, the sowing of large areas is hazardous, and the crop is therefore drilled during September and early October. Planting depth is important as shallow drilled rice seed may germinate and emerge after early showers: if long dry periods follow, mortality may be high. Seed is therefore drilled at a depth of 3in. to prevent moisture penetration by early rains.

This method of establishment is not wholly satisfactory. There is inadequate water storage for early irrigation at present, and as the nearby tidal Adelaide River cannot be used to irrigate rice until the flow is swollen by rain, and the salt content is sufficiently low for safe pumping, dry and deep drilling has appeared the most suitable method for crop establishment.

A rice variety may be one of two types: the first, known as 'season bound', is a variety which comes to maturity at a particular season of the year, irrespective of the date of sowing; the second is 'period bound', a type in which maturity occurs after a definite period from the time of sowing. Only the former has been grown at Humpty Doo, because the 'period bound' varieties usually mature after a shorter time and would have to be planted about half way through the wet season.

The varieties available at present mature at approximately the same time, with the result that the harvesting machinery is inadequate to cope with the crop, and areas which are not harvested become badly lodged and the grain suncracked. A series of varieties which will mature in succession is urgently required, and research aimed at producing varieties which will widen the harvesting period is being undertaken at the present time.

Weeds, Pests and Diseases

Weeds. Weeds are a serious problem in rice at Humpty Doo, particularly as the commercial rice areas have no early irrigation water to suppress weed growth. Weeds appear with the emerging rice and generally remain unchecked throughout the growing season. The principal grass weeds are *Panicum effusum* and *Echinochloa colonum*, while *Sesbania benthamiana* and *Melochia corchorifolia* are the principal dicotyledonous weeds. It has been successfully demonstrated by the Coastal Plains Research Station that the timely use of water during the early stages of crop establishment can control weeds.

Birds. Damage to the earlier experimental rice crops at Humpty Doo by magpie geese, *Anseranas semipalmata*, was given nation wide publicity and it appeared that the geese constituted a major problem for rice development in these areas. An investigation by the Wildlife Survey Section of the CSIRO was started in 1955; it showed that the goose eats roots and seeds and grazes on freshly grown grasses that are not too tall. Cultivated rice is an acceptable substitute for wild rice and other swamp grass. Geese will only attack a cultivated crop where there is a shortage of natural feed; this can occur when the cultivated rice ripens well ahead of the wild rice and swamp grasses, but when there is adequate alternative feed the geese will not attack the cultivated rice.

Measures to control the magpie geese involve the alteration of the breeding habitat. The geese nest in water, the depth of which has to be within narrow limits. A depth of 1-3ft. is necessary for the growth of the main feed plants, and nests are not built in deeper water. Draining a swamp to provide a quick run-off of water, or damming to increase the water level to 5ft. or more, will destroy the wet-season geese habitat.

Insects. The principal insect pests on rice are stem borers (Family Pyralidae). Two which are known to attack rice at Humpty Doo are believed to occur naturally in the area and are probably associated with wild rices: they are '*Scirpophaga*' *innotata* (Walk.) (sub-family Schoenobiinae) and *Chilotraea* sp. (sub-family Crambinae).

Stem borer attack usually starts in January and as many as seven generations of the moths may attack the rice during the growth of the crop. The insects over-winter in rice stubble and in the soil and consequently field sanitation may be an important factor in control of these predators. Research work at Kimberley Research Station in Western Australia suggests that ploughing immediately after a wet season rice crop has been harvested, kills a high proportion of the over-wintering stem borer pupae. Further research will be undertaken to check on the validity of this assumption.

Diseases. No disease has so far been recorded at Humpty Doo that incurs serious losses of grain. *Helminthosporium* occurs annually, but is usually only light to moderate in infestation. Other diseases of minor import-

Hand broadcasting pre-germinated rice seed on puddled land. A high standard of levelling has been achieved throughout the field.

A fertiliser experiment at the Coastal Plains Research Station. The rice in the centre plot has received no fertiliser.

ance are *Cercospora*, *Nigrospora* and *Curvularia*. *Piricularia* and *Entyloma* have been isolated on wild rice in Northern Australia, but not on cultivated varieties. *Fusarium* has attacked other rice crops in the Northern Territory and caused considerable damage but so far it has not been important on the sub-coastal plains.

Planting into flooded Bays

Studies into establishment and harvesting problems were initiated during the 1959-60 wet season. It was found that period bound or weakly season bound varieties of rice could be planted at intervals during January, February and March with a resultant staggering of harvesting dates. This mid-wet season establishment involves the use of specially adapted tractors and machinery which will work in rice bays flooded with water up to a depth of six inches. This early work has been promising and yields of rice of 2,240-4,000lb. per acre have been harvested.

Fertility Studies

There is considerable variation in soil fertility on the sub-coastal plains. In general, on higher areas where the clay

soil is overlying laterite, there appears to be no nutrient deficiency. Crops sown on these areas without added fertiliser make excessive vegetative growth, and although capable of producing high yields, lodge badly.

In the lower areas of the plains that were originally drainage areas adjacent to swamps, soil fertility is very low. Grain yields from these areas in the absence of added fertiliser is of the order of 1,000lb. an acre. Preliminary fertiliser experiments indicate that there is little response to either nitrogen or phosphorus alone, but there is a marked increase in yield when both fertilisers are used. Quantitative data from these first experiments suggest that fertiliser applications of the order of 20lb. an acre of phosphate and 40lb. nitrogen are required.

Varieties and Breeding

The breeding programme undertaken for the sub-coastal plains has the following objectives:

(1) Strong straw;
(2) Good grain quality with a high milling out-turn;
(3) High fertiliser response;
(4) Varieties of different maturity to enable the spreading of harvest over a longer period.

Neither of the two commercially grown varieties, Meli No. 2 and Hnan-wa-phin-gauh, possesses any two of the above combinations. Either variety may be reasonably satisfactory for sowing on comparatively small areas, but more promising varieties are warranted if the industry is to become a larger one.

There are a number of factors which may effect the straw strength of a variety (depth of water, time of sowing, and rate, time and method of application of nitrogenous fertiliser) but none of the introduced *indica* varieties can be said to be truly strong strawed. It would therefore appear that the character of strong straw is most likely to be obtained from crossing *japonica-indica* or *japonica-bulu* types. Long grain segregates from *japonica-indica* crosses are being grown under high fertility conditions so that selections for straw strength can be made and the response to fertilisers assessed.

It is usually claimed that *japonica* varieties respond well to fertilisers, and that *indica* varieties respond less. However, whilst this is true in a general sense, marked varietal differences exist within each group. It has been found at Kimberley Research Station in Western Australia that with *indica* varieties the response to increasing amounts of sulphate of ammonia is largely in straw rather than in grain. If nitrogen is added at rates of 80lb. and 120lb. per acre it has been found that *japonica* varieties have grain to straw ratios of 65 per cent. and 79 per cent. respectively. At the same levels of nitrogen, *indica* varieties have ratios of 28 per cent. and 18 per cent. respectively.

The importance of having a number of varieties maturing at different times must be emphasised. At present the area under crop on the sub-coastal plains is approximately 5,500 acres, and the two varieties sown have a similar photoperiod response and come into head at the same time, irrespective of planting time. Consequently, it is impossible to harvest such a large area of crop at the correct grain moisture content without heavy over-capitalisation on harvesting machinery.

The high proportion of suncracked grain is a problem at present and is being investigated along two lines: (a) the use of non-periodic varieties and the staggering of planting during the wet season by planting into water or mud; and (b) by pre-wet-season sowing of varieties of differing photo-period response.

Avenues for variety improvement include the introduction of new *indica* types from overseas, and the breeding of varieties adapted to the local conditions. Introductions may offer a quick method of improvement, but it is considered that the long-term approach of breeding varieties is likely to produce the most satisfactory results. Many hundreds of *indica* varieties have been introduced into Northern Australia, and none is suitable for easy mechanical harvesting as they have an inherent tendency to be tall growing with fine weak straw.

The combination of strong straw, long grain and high fertiliser response is being studied in a series of hybrids, which are showing promise at present.

Marketing

As previously mentioned, rice growing on the sub-coastal plains is confined to the cultivation of long grain *indica* types. To date, the only market that has been exploited has been in Hong Kong, where limited sales have been made. As it appears probable at this juncture that the policy will continue to be the growing of high-quality long grain types, it is of interest to consider the possible markets for the produce.

Local market. There appears to be a definite, but limited market for a high-grade product in Australia. Australians are not large consumers of rice, but little has been done to publicise long-grain rice in this country. At present, almost all rice consumed in Australia is the short-grain soft-cooking *japonica* type grown in New South Wales. It is probable that the total consumption of rice in Australia could be very greatly increased by the availability of a high-quality long-grained rice.

Overseas markets. The principal importing countries of long-grain rice are India, Ceylon, Malaya, Hong Kong, Indonesia and the Soviet Union. Markets may also be found in Africa, the West Indies and certain Western European countries (France, Spain and Italy are producers of the short-grained types).

The United Kingdom annually imports about 83,000 tons, approximately one quarter of which is high-quality long-grain rice. However, this market would probably be open only to rice of the highest qualities.

One of the major difficulties in assessing potential world markets is that nearly half of the world's trade in rice is conducted on the basis of long-term inter-governmental contracts; such long-term agreements obviously limit the opportunities of a new entrant into the rice export trade. On the other hand, the increase in the population of the world, particularly in those countries which use large quantities of rice, indicates that, in the long view, the demand may increase.

Livestock improvement by artificial insemination

by **Joseph Edwards,** C.B.E., D.SC., *Milk Marketing Board (England and Wales).*

This article discusses artificial insemination mainly in the field of cattle breeding, and deals in particular with developments in the United Kingdom. These, the author believes, have given the AI movement, internationally, leads in techniques, organisation and the scientific analysis of breeding merit. Because heredity and environment are so intermingled, it is not possible to give figures for increases in production attributable solely to AI (i.e. to the increased use of good sires), but the author shows that a method of sire selection is now available which reveals genuine breeding merit.

The initial stimulus to develop the technique of artificial insemination came from the need in Russia, after the First World War, to overcome diseases transmitted by natural service in the rehabilitation of the country's cattle and horses. Transferred to Western Europe and North America, the technique in the 1930's was adopted almost exclusively for dairy cattle breeding, the main objective being to make available to the owners of small dairy herds the quality of herd sire they could not otherwise afford. Revolutionary processes have a habit of opening out in realms of scope and possibility not foreseen at the beginning and AI is an example of this.

Today the technique is still used mainly for dairy cattle breeding—in many countries the proportion of cattle bred by AI is already 50-95 per cent.—but the emphasis has changed from an economic convenience for small herds to a genetic programme of selection on a large and scientific scale. In addition, AI is being used increasingly for beef production—among herds of the pure beef breeds and for crossing on dairy breeds—and once again methods of selection are evolving which will help in meeting the world's shortage of meat.

Finally, also among cattle, the technique is now seen to be an aid to the creation of new breeds for special purposes or to suit environmental conditions and to shorten the time needed for this. For example, it has been reported that the King Ranch, in Australia, will use AI to convert a station establishment of 35,000 Scotch Shorthorns into one of 75,000 Santa Gertrudis by a genetic plan involving the use of Brahman (Zebu) bulls and selection thereafter.

Naturally schemes of this kind may be aided greatly in the future by imports and exports of semen of different breeds or strains within breeds. The first 'international' calf was born in Essex in 1936 from semen flown from Holland. British research workers have now created a method of preserving bull semen at very low temperatures—about -180°C.—and semen may be transported anywhere in the world (with liquid nitrogen as a refrigerant) and kept alive for years. Following experiments some years ago with semen flown from the United Kingdom to Kenya, Nigeria and India, export companies, as an ancillary to the export of live animals, have been established in the United Kingdom, Holland and the USA, and the future is bright for countries in which livestock industries are emerging to meet the needs of a rising standard of living and the concomitant demand for animal products.

Sheep and Pigs

Artificial insemination for the breeding of sheep goes on on a vast scale in Russia, where the urgent task was originally the need to convert mainly hair-type breeds into wool-bearing animals, and to a lesser extent in such countries as Australia and Turkey. For pigs, the use of AI at present is marking-time in Western Europe, though it has come to be adopted quite widely in Japan. A development in technique is needed to give fertility results equal to those of natural service. There is little doubt that when the problem is solved the contribution of AI to pig breeding will be as great as it is now to cattle breeding.

One by one a number of fears and suspicions surrounding AI have been shown to be groundless, and this has paved the way for the long-term planning that is now possible. Fertility results are as good by AI as by natural service and the semen-producing ability of well cared for males is sustained for the normal span of their lives. In fact, Nature is so prodigal in this activity that no bull, however superior his genetic merit, can be used to the limit of his sperm-producing capacity. He could sire his race many times over but, of course, would not be permitted to do so. As regards the female, it is now established that her fertility performance, and also that of her descendants, is not affected negatively by insemination throughout her breeding life: in other words, the presence of the male is not essential to the normal functioning of her breeding cycles and their outward symptoms.

AI and Inbreeding

A fear that has taken longer to dispel concerns the risks of inbreeding and the effect that AI might have on them. Although there is no genetic reason for every small herd of

cows being mated to a single sire, the dramatic change so suddenly brought about by AI raised many doubts about the narrowing of bloodlines, the loss of 'genetic flexibility' and the 'depression' of commercial qualities likely to result from a reduction in the number of sires in use. This has been substantial: in England and Wales there has been a reduction from 101,000 bulls in 1942, when AI started, to 54,000 at the present time. An examination of the latter number is even more illuminating: 53,300 are in natural service and are used for approximately one million cows; 700 are at AI centres throughout the country and are used for the remaining two million cows.

To resolve this fear the opinions were sought of a number of the world's leading geneticists, to whom the proposition was put that two million cattle might be bred annually to 200 sires of known breeding merit without genetic deterioration. (The difference between 700 and 200 needs explanation. Among the former [the Milk Marketing Board's present stud] are a number of unproved sires. The first proof of their breeding merit is not available until their daughters have completed a lactation, by which time they are 6-7 years old. The ultimate aim of AI is to breed as extensively as possible for progeny-tested males with, of course, a sufficient number of young sires on test to ensure the continuity of the élite older stud. Therefore, in place of a stud of mixed ages in constant use, the proposition envisaged an élite stud of 200 in maximum use and replenished from 1,000-1,200 young bulls, each restricted to 1,000 females and then laid-off until demonstrating their worth.)

The geneticists to whom the proposition was put were asked if they knew of any grounds, substantiated by modern concepts and experiments in quantitative genetics, for doubting its feasibility. They were practically unanimous in stating that they knew of none, though they drew attention to the care needed with the smaller breed populations. (In fact, in modern poultry breeding for egg and meat production, the intensity of genetic programmes is already many times greater than that envisaged in the proposition.)

The immense significance of the sire in cattle breeding by AI forced upon all research workers in the field of applied genetics the need to find ways of increasing the accuracy of the progeny test. In the days of breeding by natural service the usual method was to compare the yields of a sire's daughters with those of their dams, and sometimes to use a formula or index to derive the sire's contribution. There were two main deficiencies in this method: first, the number of daughters was likely to be small; and second, the result was confused by the large effect of environment on both the dam-daughter comparison—conditions on the farm could easily change considerably in the years between the making of the heifer lactations of each group—and on the meaning of the level of yield attained. We know now that an 800 gallons average for a sire group in one set of conditions might, in fact, be better (genetically) than 1,000 gallons in another, but this could not be established by the proving system in use.

It is now widely understood that environment is far more important than heredity in causing differences in yield between herds. Environment is usually interpreted as 'feeding and management' but this does not mean that it is fully understood. Stockmanship and the milking technique in the cowshed are highly important factors that still defy analysis. The experimenter wishing to eliminate or control these elusive influences in his attempt to find real genetic merit would plan to study the effect of a sire not in one but in many herds, and this is exactly the arrangement which AI is able to make.

Assessment of Genetic Merit

Genetic merit for milk yield is now assessed, for all young sires brought into the proving programme, by what is known at the Contemporary Comparison method. Up to 1,000 cows are inseminated from each young bull in large numbers of milk recorded herds, and when their heifers come into milk each progeny group is judged against the contemporary performance of the daughters of other bulls —in the same herds and in the same season. The first assessment is made after 180 days in milk, and the really bad sire can be eliminated at this stage. The final 'proof' is made when 305-day lactations are completed, and the decision is made whether or not to bring the sire into full use.

Factors besides milk yield have to be taken into account. The butterfat content of the milk must be satisfactory and soon, as is now done in the Netherlands, the UK may test for protein content as well. In addition, evidence must be provided that a good commercial type of daughter is being bred: this is judged by MMB 'breed panels'—who carry out inspections farm by farm to assess anatomical characters such as legs, feet, body conformation and udder shape, as well as dairy temperament. To pass all these tests a bull must be very good indeed and if he is really outstanding he is placed on a Sire Nomination List (see Table 1).

This list, drawn up and published each autumn, is one of the very real achievements of AI. In the past a breeder was fortunate if he could, for special matings in his herd, borrow or hire another breeder's bull and he took the risk of introducing disease in doing so. Today, thanks to storage of semen at very low temperatures which makes possible its transport throughout the UK, he has available to him not one but 100 sires of proved breeding merit. Wherever the sire may be—he may even be dead—the breeder has only to lift the telephone and a service is arranged. The increasing popularity of a choice of this kind is shown by the demand in the past four years:—

	Number of Nominated Services
1957	24,200
1958	31,400
1959	48,600
1960	57,000 (provisional)

Young sires brought to AI centres for proving have to be well enough bred to satisfy those who choose them and those in whose herds they are used. Today it goes without saying that the father of a young bull must be thoroughly progeny tested, and the increasing use of Nominated Sires is such that the MMB's need is now less urgent than it was

Table 1

National Nomination Bulls standing at Milk Marketing Board centres.

Name of Bull	*Gallons Milk*	*Per cent. Butter-fat*	*No. of Heifers*	*Age at Calving (in months)*	*Contem-porary Comparison (in gallons)*	*Conformation of Daughters*						
						Dairy Tempera-ment	*Milking charac.*	*Udder*	*Teats*	*Legs and Feet*	*Body*	*General Appearance*
AYRSHIRE												
Bankend Parade	881	4.13	59	32	+ 19	V. Good	V. Good	V. Good	V. Good	V. Good	V. Good	V. Good
Bankend Pearlstone	877	4.09	40	32	+ 70	Good	Good	Average	Average	Average	Good	Good
Barnes Sportsmaster	763	4.14	36	32	+128	Good	Good	V. Good	Good	Good	Good	Good
Cowgrove Famed Brand	914	4.28	30	28	+ 65	Good	Good	Good	Good	Good	Good	Good
Eyton Snowflake	815	4.13	56	31	+ 25	Good	Good	Average	Good	Good	Good	Av.-Good
Howies Artist	885	4.25	32	34	+ 70	Good	Good	Average	Good	Average	Good	Good
Kemsing True Blend	788	3.85	218	30	+ 55	Good	Good	Good	Good	Good	Average	Average
Lessnessock Pendragon	839	4.20	27	32	+ 46	Good	Good	Good	Good	Good	Good	Good
Logan Mains Flagship	856	3.95	64	30	+ 85	Good	Good	Good	Good	Good	Good	Good
Logan Mains Knight	906	4.03	34	33	+ 76	Good	Good	Good	Good	Good	Good	Good
Manrahead Diamond	813	4.18	166	31	+ 39	Good	Good	Good	Good	Good	Good	Good
Preston Majesty	921	3.93	46	33	+ 61	Good	Good	Excellent	Excellent	Good	Good	Good
Preston Mariner	828	4.08	30	35	+141	Good +	Good	Good	Good	Good +	Good	Good
Willoxton Lord Nelson	787	3.97	86	31	+ 21	Good	Good	Average	Good	Good	Good	Good
FRIESIAN												
Alsopdale Janrol	949	4.14	27	35	+ 43	V. Good	V. Good	V. Good	V. Good	Good	Good	Good
Gloryfarm Tempestuous	847	3.80	29	27	+ 43	Good	Good	V. Good	Average	Good	Good	Good
Greenlands Hiltedeuwk	1027	3.63	57	32	+ 54	Good	Good	Average	Average	Good	Good	Good
Highmill Trueman	913	3.62	112	31	+ 78	Good	Good	Good	Good	Good	Good	Good
Hunday Betreme	848	3.96	66	31	+ 18	Good	Good +	Good	Good	Good	Good +	Good
Ironside Texan	980	3.58	230	32	+144	Good	Good	Average	Av.-Good	Good	Average +	Average
Lavenham Adventurous	1051	3.76	51	35	+ 56	Good	Good	Average	Good	Good	Average	Average
Lavenham Catchword	899	3.66	140	31	+ 73	Good	Good	Good +	Good +	Good	Good	Good
Lavenham Critic	932	3.72	35	33	+113	V. Good	V. Good	Good	Good	Excellent	Good	Good
Lavenham Gratitude	1044	3.81	31	33	+ 75	Good	V. Good	Good	Good	Good	V. Good	V. Good
Lavenham Prospector	917	3.60	41	33	+ 40	Good	Good	Good	Good	Good	Good	Good
Lavenham Welbred	1208	3.61	33	28	+112	Good	Good	Average	Good	Good	Good	Good
Mayford Coronet	1025	3.83	30	31	+ 43	Good	Good	Average +	Good	Good	Good	Good
Mayford Random	1136	3.54	88	34	+108	Good	Good	Good	Good	V. Good	V. Good	V. Good
Mayford Welldone	1015	4.00	20	31	+113	Good	Good	Good	Good	Good	Good	Good
Minsden Guardsman	955	3.60	47	32	+ 60	V. Good	V. Good	V. Good	Good	Good	Good	Good
Montgomery Jan Gort	853	3.61	70	31	+ 35	Good	Good	V. Good	V. Good	V. Good	V. Good	V. Good
Parkhouse Keesteen 3rd	870	3.68	291	33	+ 37	Good	Good	Av.-Good	Average	Average	V. Good	Good
Pitsea Met Rooske 11th	863	3.59	213	33	+ 32	Good	V. Good	Good	Good	Good	Good	Good
Plasnewydd Alycidon 2nd	947	3.96	138	30	+ 47	Good	Good	Good	Good	Good	Good	Good
Plasnewydd Archer	903	3.66	195	31	+ 59	Good	Good	Average +	Good	Average +	Good	Average +
Warden Pathfinder	882	3.89	239	31	+ 46	Good	Good	Good	Good	Good	Good	Good
Wintersell Bengal	893	3.57	104	33	+ 70	Good	Good	Good	Good	Good	Good	Good
GUERNSEY												
Birchwood Montrose 4th	754	4.85	25	29	+126	Good	Good	Good	Good	Good	Good	Good
Ridgeway Downs Sailor Boy	696	4.77	178	31	+ 53	Average +	Average +	Good	Average +	Good	Average +	Good
Rockbeare Maple Lad	741	4.73	12	31	+ 55	Good	Good	Good—	Average	Good	Good	Good
Widford Roberts Lad 2nd	761	4.78	55	31	+ 38	Good	Good	Good	Good	Good	Good	Good
JERSEY												
Bollhayes Jolly Knight	650	5.05	77	25	+ 49	Average	Good	Average	Average	Good	Average	Average
Firethorn Tamburin	654	5.09	194	27	+ 45	Good	Good	Average	Good	Good	Good	Good
RED POLL												
Grundisburgh Paddy	809	3.63	53	37	+111	Good	Good	V. Good	Good	Good	Average—	Average
DAIRY SHORTHORN												
Bellmount Brilliant Boy 2nd	700	3.60	43	35	+119	Good	Good	V. Good	V. Good	V. Good	Good	Good
Chalfield Fairy Knight 44th	653	3.64	119	34	+ 40	Good	Good	Average	Good	Good	Good	Good
Longhirst Lord Wildeyes 2nd	895	3.69	24	32	+ 53	Good	Good	Good	Good	Good	Good	Good
Orma Barrington Supreme	779	3.89	45	35	+ 63	Good	Good	Good	Good	Good	Good	Good +
Redrice Senator Beau	754	3.91	24	34	+ 42	Good	Good	Good	Average	Good	Good	Good
Stockwood Playboy 3rd	853	3.63	31	35	+ 19	Good	Good	Good	Good	Good	Good	Good

to make 'contract matings' with breeders. There is also the hope that breeders will organise themselves in syndicates to prove once more, with the help of the AI movement, their own young bulls in a number of herds. If they do they will possess the alternative of either selling young unproved bulls to AI or holding on to them with the opportunity later of selling the bull or his semen at a much higher price.

Information in a Pedigree

Thirty years ago a pedigree of a dairy bull contained three important pieces of information: the records of the dam and the records of the maternal and paternal grand-dams. Some might wish to go back further but always on the female ancestry. Today the pendulum has swung completely to the male side: and an analysis of prices of sires at the leading sales shows that money is being paid for the progeny records of the sire and the maternal and paternal grand-sires. There is no doubt that the pendulum will swing again, for every bull has to have a mother (and grandmothers) and, after all, in breeding for milk we are selecting for an extreme female characteristic.

We can expect to see a new concentration of research on the female contribution to the inheritance of young bulls that are to be tried out. Even now, in assessing the records of a bull's dam a study is made of her performance relative to her herd-mates. How do her lactations compare with

those of her contemporaries year by year? It is some achievement if in the 'survival of the fittest' she excelled over a number of lactations but, of course, she may not transmit her superiority. (Referring once more to the elusive art of stockmanship, the attempt has to be made in analysing a cow's performance to rule out the possibility of special treatment, and by this is meant not only a box to herself with extra food and exclusive attention, but also the signs that she has received 'favoured cow' treatment because the herdsman liked her.)

Analyses of all living female relatives together with those of recent female ancestors may be shown to have something valuable to contribute. However, the most important progress that can be desired lies in the field of super-ovulation. To equal the value of the progeny test as a measure of the sire's genetic merit (now available though AI), it will one day be necessary to sample the cow's transmitting ability by testing not the small number of daughters she may bear in her lifetime in the natural way, but the much larger numbers created by hormone injections that result in many more eggs from her ovaries and the successful implantation of these in 'host' mothers. The first part of this problem—super-ovulation—is already solved. Successful implantation still eludes us though no doubt it will yield to research one day.

Commercial Objective

In the selection of males and females for breeding the fundamental objective is a commercial one. The subject is not yet, and may well never be, a task for electronic computers, although without the use of the most up-to-date machines the researches of the animal geneticist would suffer greatly.

Tradition dies hard and the new knowledge of the relative effects of environment and heredity and their interaction takes time to produce its results. Even the Contemporary Comparison concept brings with it an upheaval in our thinking. For decades it was believed by breeders that any pedigree bull with a respectable pedigree would bring about genetic improvement in a non-pedigree commercial herd: and that it would be dangerous to introduce an aristocratically bred sire to a herd at a low level of production, because his daughters, being inadequately cared for, would milk themselves to death. The Contemporary Comparison results show that this is not so. Superior genetic merit (see Table 2) reveals itself at all levels of production: a bad bull lowers production not only in high-yielding herds but also in those at a much lower level. The reverse is also true.

Of what does real genetic merit consist? The evidence quoted above suggests above all a will to survive, whatever the conditions. One day this will be analysed in basic terms, including those of physiology and anatomy. We know remarkably little about the size and liveweight of our breeds of cattle, largely because weighbridges are not normally found on farms. No breed society defines what the mature size or weight of animals of its breed should be and fashions have fluctuated from large types to small. Yet it is well established that (a) large animals consume more

Table 2

The performance for milk yield of good, mediocre and poor bulls at different levels of herd production.

	Con. Comp. Low Herds (gals.)	*Con. Comp.* Medium Herds (gals.)	*Con. Comp.* High Herds (gals.)	*Con. Comp.* All Herds (gals.)
19 Good Bulls	+76	+69	+45	+60
19 Average Bulls	+17	0	— 3	+ 5
19 Poor Bulls	—45	—54	—84	—61

N.B. No bull in this study had less than 130 daughters in milk and the largest number by one of them was 342.

to keep alive and (b) that at a given liveweight it is physiological efficiency—the ability to convert the maximum amount of food eaten into milk—that pays dividends.

Increasingly facts about weight and size are being collected, mobile weighbridges having been introduced to travel from farm to farm in connection with sire-proving programmes. Soon we shall be able to describe genetic merit in terms that take liveweight into account and so the term 'efficient strain' will acquire a more precise meaning. This will bring cattle breeding closer to the concept of the efficiency of an internal combustion engine, including its petrol consumption, though even now the evidence is that the cow is a far more efficient converter of energy than the best non-nuclear device.

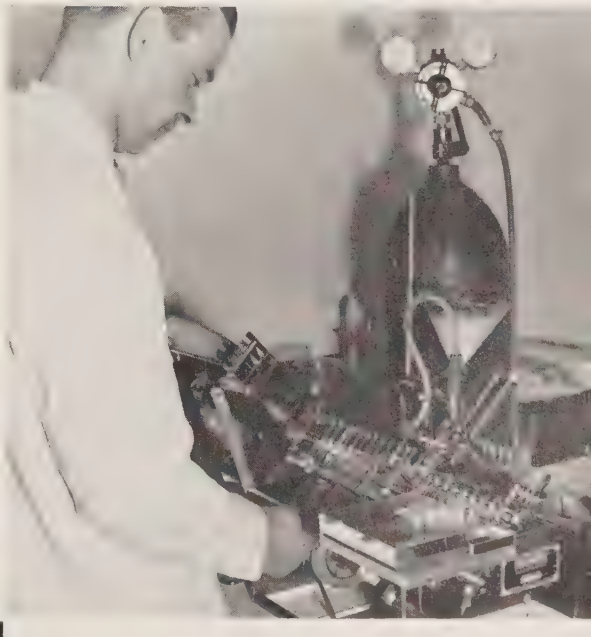
Beef from the Dairy Cow

This may turn out to be as significant for meat production as for milk. Britain's dairy herds, either from pure Friesian breeding or from crossing with her well-known beef breeds, must supply more than half of the country's meat, and the genetic pattern of growth and development for the efficient dairy animal may well show itself to be not so very different from the lean meat animal now in demand.

In many parts of the world where vast and cheap land areas exist—on the plains of the USA and the pampas of the Argentine, for example—meat production is on extensive lines. But where these conditions do not obtain, animals for meat will increasingly have to come from dairy herds.

In England and Wales 30 per cent. of all dairy cows bred by AI are crossed with bulls of well-known beef breeds, such as the Hereford and Aberdeen Angus, and the importance of the sire may be judged from the fact that one bull in the MMB stud had sired 40,000 calves to the time he died. There is a world shortage of beef and it is likely to remain for some time, because of the rapidly increasing world population and the fact that an increase in the demand for beef is everywhere an inevitable result of an increase in living standards. The future is likely to see solid achievements in the use of AI for beef production that will match its achievements of the past 15 years in breeding for milk.

This Hereford bull, Freetown Focus, bred over 50,000 calves through AI.



The modern equipment at the Milk Marketing Board's deep-freeze unit includes this automatic sealing machine.

Frozen semen can be exported for breed improvement or experimental purposes. This Ayrshire x Hungarian spotted calf, seen with its mother, is the result of such an export.

Control of cereal pests in Britain

by **J. L. Hunt,** *Shell Chemical Company, London.*

Since pre-war days, the production of grain in the United Kingdom has nearly doubled. This notable increase in productivity is attributable mainly to the higher yield potential of modern cereal varieties and the more generous fertiliser treatment which they now receive, but the widespread application of herbicides to prevent weed competition and of insecticides to protect the crop against insect pests are also important contributory factors to higher production.

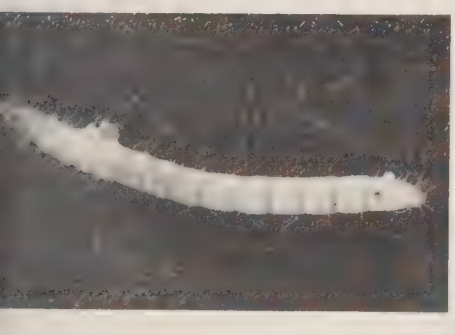
Cereal pests of particular economic importance in the UK are wheat bulb fly, wireworms, frit fly and leatherjackets. Before the introduction of chlorinated hydrocarbon insecticides, control of these pests largely amounted to taking avoiding action by appropriate choice of land for the cereal crop, and by adopting various cultural means designed to limit the scale of infestation and enable the crop to withstand attack. The only chemical control measure adopted to any extent was the use of Paris Green/bran baits to destroy leatherjackets.

Since the war, DDT, γ-BHC, aldrin, dieldrin and heptachlor have become available for use in various ways, and the situation has changed completely. These insecticides have replaced Paris Green for use in bran baits to destroy leatherjackets, and they are also widely used in low volume sprays against leatherjackets and frit fly. Aldrin is also incorporated in compound fertilisers to control wheat bulb fly, but the most outstanding development in the field of cereal pest control has been insecticidal seed dressing, the use of which against wheat bulb fly and wireworm is now the rule rather than the exception. This method of control appeals strongly to the farmer on the grounds of low cost and convenience.

Until recently, only powder seed dressings containing organomercurial compounds for disinfection against seedborne diseases, and γ-BHC, aldrin, dieldrin and heptachlor as the insecticidal component, have been used in this country, the insecticide being applied at 0.02-0.06 per cent. of the weight of seed. In 1959, Shell Chemical Company pioneered the technique of liquid seed treatment in the UK, and by arrangement with Casco Limited, of Sweden, introduced the liquid organo-mercurial compound Panogen, together with Astex, a liquid formulation of dieldrin. Other liquid preparations containing aldrin and heptachlor quickly followed, and it seems probable that liquid seed treatment will increase in popularity.

Within certain limits, referred to later, insecticidal seed dressings have proved effective protectants of cereals in the early stages of growth and, generally speaking, aldrin, dieldrin, heptachlor and γ-BHC are of approximately equal efficiency.

Seedlings of winter oats damaged by frit fly, Oscinella frit *L.*



A wireworm, the larval stage of Agriotes *sp. Oats and spring wheat are especially susceptible to wireworm attack in the early stages of growth.*

A male wheat bulb fly, Leptohylemyia coarctata *Fall. This insect is a serious pest of winter wheat in many parts of Britain.*

As previously mentioned, the insect pests of cereals which are of particular economic importance in Britain are wireworms, *Agriotes spp.*, wheat bulb fly, *Leptohylemyia coarctata*, frit fly, *Oscinella frit* and leatherjackets, *Tipula spp.*

Wireworms

The crop sustains damage by wireworm in the early stages of growth, mainly in the spring, oats and spring wheat being particularly susceptible.

The need for increased home food production during and immediately after the war necessitated a substantial increase in our arable acreage, and involved a large-scale programme of ploughing out permanent pasture, much of which was heavily infested with wireworm. The general pattern of British farming has now become more stabilised, with a comparatively constant ratio between grass and arable cropping. The reduced acreage of permanent grass which is now ploughed for arable cropping, and the extensive use of aldrin and dieldrin for control of soil pests in recent years have resulted in the wireworm becoming a pest of considerably less economic importance, but farmers still like to take appropriate steps to insure against damage to their cereals, sugar beet and potatoes.

The insecticidal seed dressing, applied together with an organo-mercurial seed disinfectant, is the standard measure of control adopted. Provided the wireworm population is not too high, this seed treatment will usually give adequate protection of the cereal crop in the seedling stage and enable it to withstand limited attacks after the deterrent effect has worn off. Heavy infestation at this stage may, however, cause severe damage.

The effects of insecticidal seed dressings on the yield of cereals and on the wireworm population have been studied at Rothamsted Experimental Station. An experiment with winter wheat carried out over a two-year period compared the effects of BHC seed dressings with BHC broadcast over the ground before drilling and combine-drilled with the seed. It was found that the seed dressing increased the yield in the first year, but had no residual effect in the second and no significant effect on wireworm population. On the other hand, the much larger quantities of insecticide broadcast and combine-drilled gave substantial yield increases in the first and second year and appreciably reduced wireworm population over the two-year period. Aldrin combine-drilled and broadcast had a similar effect.

It would seem, therefore, that insecticidal seed dressings mainly have a deterrent effect against wireworms and that this effect is of short duration. There is evidence, however, that seed dressings can kill wireworms if they attack the ungerminated or newly germinated seed. This is most likely to occur with late sown crops, whereas with early sown crops the effect of the seed dressing will have largely worn off by the time the wireworms become active, and they will tend to attack the shoot. In this latter case, they

may be deterred by insecticide translocated to the shoot, but they will not be killed.

It can be concluded that seed dressings are appropriate for use where wireworm populations are low, and this applies in most cases at the present time; but with heavy infestations, combine-drilling or broadcasting of aldrin, or the use of a fertiliser containing aldrin, should be adopted.

Wheat Bulb Fly

Wheat bulb fly is a serious pest of winter wheat in many parts of the country, particularly East Anglia and Lincolnshire, and until fairly recently an effective means of chemical control has not been available. Credit for rectifying this deficiency is due particularly to Dr. H. C. Gough and his colleagues in the National Agricultural Advisory Service and to Rothamsted Experimental Station, who have carried out a well planned and coordinated programme of investigations and field trials during the last few years. These investigations, supported by large-scale extension trials, have demonstrated that a considerable measure of control of wheat bulb fly may be obtained by the use of aldrin, dieldrin, heptachlor and BHC seed dressings, and also by combine-drilling aldrin incorporated in fertiliser. Seed dressing is usually the preferred method, being more effective and cheaper. A higher rate of dressing is employed for wheat bulb fly control than for wireworm—0.4-0.6 per cent. of insecticide to weight of seed, compared with 0.2 per cent.—and this dressing against wheat bulb fly will also, of course, control wireworm.

Wheat bulb fly eggs are laid in the soil in August and September, some six months before they hatch, and the larvae reach the plant from near the soil surface. It is unlikely, therefore, that they are killed by contact with the seed, to any appreciable extent, except with very shallow drilling. Some larvae may be destroyed by fumigant action or by contact with insecticide picked up by roots and shoots emerging from the germinating seed, but the toxic effect is thought to arise mainly from insecticide translocated systemically from seed to shoot. It is now established that aldrin, dieldrin and heptachlor used as seed dressings have systemic action, and that although a wheat bulb fly larva may destroy the first shoot of the young wheat plant, it will be killed before doing further damage.

Frit Fly

Oats are particularly susceptible to damage by frit fly, the seedling plant being attacked by the first generation of maggots and the developing grain by the second generation. Winter wheat sown after an infested ryegrass ley may also be severely damaged and young leys are frequently attacked in the seedling stage. Frit fly is also the principal pest of maize.

The seed dressing technique has proved to be unsuitable for controlling frit fly. A probable explanation of this is that frit fly eggs are laid both on the plant and in the soil. Larvae hatching from eggs laid on the plant will not come in contact with the insecticide and those hatching from eggs laid in the soil enter the plant at soil level, well above the seed. Experiments with dieldrin dressed seed sown at various depths have shown that a partial kill of larvae is obtained from very shallow sowing, but this is impracticable.

However, it is possible to obtain a fair and sometimes a good measure of control of frit fly, by spraying with dieldrin or DDT emulsion when oats are in the one-to-four leaf stage in early May. With good timing, one dieldrin spray (0.5 per cent. dieldrin in 25gal. of water per acre) is effective, and it will often be possible to combine this insecticide spray with an application of MCPA to control weeds. The control obtained against frit fly at this stage will often reduce the severity of later attacks by the second generation.

Spraying maize with dieldrin emulsion (0.5 per cent. dieldrin per acre) has also proved effective and is recommended as a routine application. The spray should be applied as soon as the first seedlings emerge and repeated 10-14 days later. High volume application is necessary to wash the insecticide down to the germinating seeds. A placement spray directed on to the rows of seedlings is often used.

Leatherjackets

As with frit fly, seed dressings are ineffectual against leatherjackets, which are sporadic in their attacks, but often devastate a crop in a very short space of time. Cereals grown after a ley are particularly vulnerable, and the risk of infestation in this case can be minimised by early ploughing of the ley before egg laying starts.

Two alternative remedies against leatherjackets are available—spraying with DDT, aldrin or dieldrin emulsions, or broadcasting insecticide bran baits. The former method is more popular with farmers who possess crop spraying machines because of its convenience and speed of operation, but the success of spraying is largely dependent upon the weather. In fairly warm, damp weather, a good control may be expected, but results are often less satisfactory in cold, dry conditions. Spraying in late afternoon or evening will often give improved results. Here again, it may be feasible to apply a combined insecticide/herbicide spray if the corn is at the right stage for the latter application.

The use of broadcast baits against leatherjackets is on the whole a more reliable method of control and, as previously mentioned, the old remedy of Paris Green and bran has now been largely superseded by baits of bran with one of the chlorinated hydrocarbon insecticides: 1½oz. of aldrin or dieldrin, in the form of dust, wettable powder or emulsion, mixed with 25lb. of moist bran and broadcast evenly over the crop at the rate of 35-40lb. per acre will usually give a reliable control. Whatever method of control is employed, it is essential to take prompt action at the first signs of attack if serious damage and loss of crop is to be avoided.

It should be noted that if aldrin is applied broadcast to the soil before sowing a cereal crop against wireworm, leatherjackets will also be controlled, and if a high infestation of leatherjackets is anticipated, this pre-sowing treatment is worth consideration.

Compiling crop statistics in the tropics

by **K. E. Hunt,** *Agricultural Economics Research Institute, Oxford.*

Agricultural statistics can be of great use in preparing basic development plans and in improving the marketing of farm products. However, the difficulties to be faced in preparing such statistics—no lists of farmers; shortage of trained staff, etc.—are formidable, and in many tropical countries few have been compiled. Nevertheless, pioneer surveys in a number of areas have led to the development of sampling methods as a successful means of attacking the problem, and in the following article the main features of these are outlined.

The contribution of statistics to the conduct of affairs is well summed up in the closing words of Sir Geoffrey Heyworth's presidential address to the Royal Statistical Society. 'One begins with a judgement and ends with a judgement. The use of figures is to come in the middle in order to make the judgement with which one ends more accurate than that with which one began'. Both businessmen and administrators in many tropical countries would be better placed to make their decisions if more agricultural economic statistics were at their disposal.

The situation is far better than it was even a decade ago, but progress is slow. The collection of agricultural statistics is no light job even in advanced countries where farms are reasonably stable from one year to another, and farmers can be ordered (or persuaded) to make postal returns of their farming activities. It is not surprising that progress is slow in tropical countries when we remember the vast areas which often have to be covered, the illiteracy of the farmers, and the shifting cultivation and extensive mixed cropping which often complicate the agricultural pattern (1).

Choice of Statistics

Little less of a problem, though it has attracted nothing like as much attention, is that of making a wise choice of data to be collected with the limited statistical resources available. It is often far from easy for those who would use the figures and those who have to collect them to find common terms in which to communicate with each other and reach some common approach to an appraisal of cost and benefit.

For example, it is often said that estimates of crop production are of value in planning the transport needed to move an export crop to the distant consumer. If we look hard at this, however, it becomes clear that only a forecast available well before the crop begins to move to market can have any operational usefulness (4). A rough, but early indication of whether the crop will be above or below normal might well be more useful than a precise estimate, to the last hundred tons, which is not available until some weeks after the crop has moved. Again, given accurate production figures, with local detail, for all main food crops, some useful pointer to the food situation might emerge, but it was difficult enough to secure operationally useful data on these lines even in Britain in wartime. Will this line of attack really improve official judgements about the food situation of subsistence farmers?

Land-use Data

Tropical countries differ greatly in the supply of staff and the availability of records to provide the basis of a sampling scheme. Parts of the Indian sub-continent have settled agriculture with maps on scales of 1:10,000, or larger, on which every little plot of land is marked and numbered. In contrast, in parts of West Africa cultivation is shifting, mixed cropping is the rule and even small-scale maps are rather rough. Perhaps the latter area provides the best illustration for this article. Probably the most detailed record available for use as a 'frame' from which the sample is to be drawn will be a list of villages, arranged by administrative districts; we must expect to find various peculiarities in it (3).

Among the basic needs in many tropical areas are data on land use and on production of crops. Though associated to some degree, land use and crop acreage estimating usually need rather different techniques. Statistics of the area of cultivated land, bush fallow, potentially cultivable land, forest, etc., may be of interest, but more often than not it is as important to know where the various uses occur as to know how much land they occupy. In other words, a map is as important as a table of statistics. Though a few studies have been made of land-use by driving parallel transects across the piece of country concerned, the work is arduous in the extreme and usually has been undertaken only where the pressure of over-population has created a critical problem. Air surveying seems the most promising approach to a study of land utilisation and provided that the greater part of the cost of such a survey can be assigned to general topographical mapping work the use of this technique may be economic.

Crop Acreage Estimates

Typically, crop production estimation is dealt with in two stages—the first designed to provide an estimate of the productive area, and the second to give an estimate of the average yield per unit of productive area. The technique of estimating crop area might be regarded as providing a general-purpose sample design capable, with suitable

Boundaries between cropped land and the bush from which it was cleared may be ill-defined. When, as here, planting is on mounds, the boundary may be clear but very irregular.

Mixed cropping presents the statistician with many recording problems. In this plot there are maize, cassava, banana, pawpaw, oil palm and a few plants of other useful species. The problem is to divide the area realistically for recording.

To give a useful indication of the state of food supplies special food consumption studies are necessary, for which the enumerator must always be present to weigh the food. Here, plantains are being peeled and wrapped for cooking.

adaptation, of being applied to many estimation problems. A two- or three-stage stratified random sample is the basic design most frequently used.

A typical sampling survey to collect information on crop acreages might proceed somewhat as follows. After assigning each administrative district in the country to a type of farming area (i.e. to a stratum), a selection of districts is drawn at random from within each stratum to give the first-stage sample units. From within each first-stage unit a random selection of villages is drawn to give the second-stage units.

Arrangements are then made to send enumerators to the selected villages and it is usually at this stage that questions about the accuracy of the frame begin to present themselves. A village may be found to have been moved bodily to a new site, to have become divided, or to be represented on the ground by a heterogeneous collection of dispersed groups. The purpose of the enumerator's work is twofold: basically he is to secure for that village the information which the survey is designed to record, but he must also test his frame at every step in the recording process. Where discrepancies are found they must be corrected in consultation with his supervisors.

There may well be no record of the names of individuals, and once at the village the enumerator prepares a complete record of the people who live there. Starting with the headman's house, he proceeds systematically from house to house up and down the street, if it is laid out as a street; or in a spiral fashion, working outwards from the headman's house, if the houses are arranged on no fixed plan. At each house, or compound, or whatever may be the local equivalent, he lists the adults in residence there, indicates which are farmers, and numbers each house before he leaves. At the end of his recording of the village he will have a complete list of the farmers of the village.

This routine of listing the village households may omit certain members of the community because they live at some distance. The head of the village must therefore be asked whether there are any hamlets or camps associated with the village, and if so, where they are. The enumerator may have to travel long distances to include the householders in these hamlets. Questions to the householders on the whereabouts of other members of the family or of hired workers may bring to light other marginal cases. If they are assignable to the sample village all must be recorded. Knowledge of the usual social organisation in the locality and of the agricultural practice needs to be used to the full to check the completeness of the basic records.

If in total these people present him with a recording problem which is within his means without further sampling, the enumerator proceeds to make his record of the acreage data required. If he must take a further—third-stage—sample it can be drawn as every n'th name on the list of farmers. Each selected farmer is asked to state what fields he has under the crops concerned. These are listed in order of the year in which they were cleared from bush, and any departures from the pattern which is to be expected in the light of local rotational practice is queried as a further

check on the completeness of the frame for this stage. When the list for each household is complete the farmer is asked to take the enumerator to each field in turn; here the record of crops is made—in many instances by conducting a chain and compass survey of each unit of land. These records are then returned to headquarters to be drawn out and the area computed. The mean area per unit in the sample is then 'raised' to give a national total by reference to the sampling fractions used at each stage.

Crop Yield Estimation

The next step towards producing an estimate of total production, namely the estimation of the average yield per acre, raises substantial problems of its own (2). Much the greater part of the crop yield estimates in the world as a whole is based on the judgements of crop reporters. Many tropical countries have no body of men who are competent to carry out such reporting, and the possibility of objective estimation by cutting a sample of crops at harvest has been widely explored. Basically the procedure follows the familiar multi-stage sample design. Usually a selection of fields is made within each sample village, and within each field small plots are sited at positions determined at random; when the crop is ripe the product of these plots is carefully harvested and weighed.

Although experiments have indicated that the cutting of a few hundred plots of, perhaps, 100 or 200sq. ft., properly distributed over the country according to scientific sample design, should secure an estimate of mean yield per acre with a standard error of, say, 5 per cent., there have emerged certain problems of bias which have not been altogether easy to control. Numerous reports have been made of estimates prepared in this way being significantly higher than either those based on eye estimation or those based on the cutting of the crop by ordinary commercial methods later on.

Though heavier losses in harvesting than in the sample cutting procedure may explain part of the discrepancy, there seem to be other influences, too. The effect seems to be greatest with very small sample cuts—say, 1 metre square. Probably in siting such a small plot under certain conditions the field man can, consciously or unconsciously, move it so as to avoid a bad patch of crop. He may also include a few ears which in fact ought to be outside the plot boundary and he may tend to ignore part of the field margin which was regarded as under crop when the area was estimated. Strict supervision of field staff and the use of a plot of fair size—say, a tenth of an acre—may help to overcome the risk. However, it seems highly desirable when starting such work to test out the method on a crop for which a reliable indication of production is ultimately available from other sources. Thus for cotton, ginnery records might provide such a cross check, and for groundnuts, customs records of quantities exported might give a useful guide.

Area frames

When the required information can be obtained by observation without the cooperation of the farmer and where most of the land is under crops, area frames can provide an efficient basis for a sample design. In other words, the collection of map sheets covering the country replaces the administrative record as the frame. The first-stage units could be single map sheets, the second-stage units square areas sited at random on each first-stage unit. However, if the maps are poor, the farmers suspicious, or little of the land is under crop, the use of the area frame meets with difficulties.

Case Studies

Though such surveys as these are typical of statistical work in some tropical areas, it may very well be that the recording of a much wider range of information on a very small sample may be well worth considering on occasion. This might arise in two ways. First, the economy of an enquiry of this kind depends on being able to move staff from one point to another with ease and precision, or on having staff resident within range of each sample unit. If the planning of staff movements proves difficult it may be found desirable to leave them in one village for long periods. During this time they might very well extend their enquiries to embrace details of agricultural and rotational practice, marketing, prices received, direction of trade, labour employed, and similar matters which would normally be regarded as subjects for agricultural economic enquiries rather than routine statistical recording.

Furthermore, if orthodox sampling enquiries can only be made at long intervals, and using small samples, it is unlikely that, for the time being, they will yield estimates of much operational value. In such circumstances, background information on the working of village economies drawn from a few case studies may be as valuable as scattered national statistics of dubious accuracy in 'making the judgement with which one ends more accurate than that with which one began'.

All told, the problems facing the statistician and the agriculturalist in this work are considerable. Not the least of the difficulties arises from the fact that much tact and skill may be needed in extracting from reluctant farmers the information necessary to gain reliable results from statistical enquiries. The kind of man who is likely to do this with the greatest success is one who is also likely to be eminently suitable as an agricultural instructor, extension officer or whatever may be the local equivalent. Men of such talents may be rare in many tropical countries and it needs some thought to decide how many should be used in recording agricultural progress and how many in promoting it.

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(2) PANSE, V. G. *Estimation of Crop Yields.* FAO, 1954.

(3) ROYER, J. *Handbook on Agricultural Sampling Surveys in Africa. Principles and examples.* FAO Mimeo, 1957.

(4) SANDERSON, F. H. *Methods of Crop Forecasting.* Harvard University Press, Cambridge, Mass.

Improving the reliability of

Many of the newer herbicides being developed for the control of annual weeds in crops are only effective if they are applied to the soil, either before the crop is sown or shortly afterwards before the weeds have emerged. In either case they have to reach the roots of the weed seedlings in sufficient concentration to be lethal. Some of these herbicides are volatile and have to be incorporated into the soil to avoid loss into the atmosphere; the others if not incorporated rely on rainfall to wash them into the soil and are therefore particularly liable to be affected by weather conditions after application. Many of these herbicides are expensive and for weed control in crops grown in widely spaced rows it is desirable to apply them as bands over each row, the inter-row areas being left untreated for subsequent cultivation.

A prototype machine, at present known as the spray-incorporating drill (SID), has been developed as a tool that will apply a herbicide in bands, incorporate it to the required depth with some precision, and finally sow a crop, all in one operation. It is hoped that more uniform results with soil-acting herbicides will be obtained than if the herbicides are either applied to the soil-surface after sowing or roughly incorporated by conventional farm equipment. It also provides the economy offered by band application.

SID is a joint project between the Agricultural Research Council Weed Research Organisation, Oxford, the National Institute of Agricultural Engineering, Silsoe, and the Norfolk Agricultural Station, Sprowston. The machine consists of a frame supported on the hydraulic lift of a tractor at the front and on castor wheels at the rear. On this frame is mounted a spraying unit operating up to four jets, two rotary cultivators driven from the tractor power take-off and four precision drills. Provision is made to add another two rotary cultivator units. Some idea of its construction can be obtained from the accompanying photographs.

Trials so far have been aimed mainly at perfecting the mechanical performance of the equipment, but promising results have been obtained with a number of crop, weed and herbicide combinations. Obviously with a technique such as this which involves the incorporation of the herbicide immediately before sowing, crop damage can only be avoided by the use of sufficiently selective herbicides, the factor of 'depth-protection', a feature of conventional pre-emergence treatments, having been eliminated.

At present SID must be regarded as a tool for research workers, but the design is such that should the technique be required for farm use, little development work would be necessary on the part of manufacturers in order to produce a commercial version.

Further details of SID can be obtained from the two following papers:

FRYER, J. D., PARKER, C. and WOODFORD, E. K. The Spray-Incorporating Drill. A machine designed to improve the reliability of soil-acting herbicides. *Proc. 5th Brit. Weed Control Conf.* (1960) (in press).

CHALMERS, G. R. and KEMP, D. C. Plot drill with sprayer equipment for experiments on pre-emergence control of weeds by herbicides. *J. Agric. Eng. Res.*, **5**, 4, 1960.

J. D. FRYER.

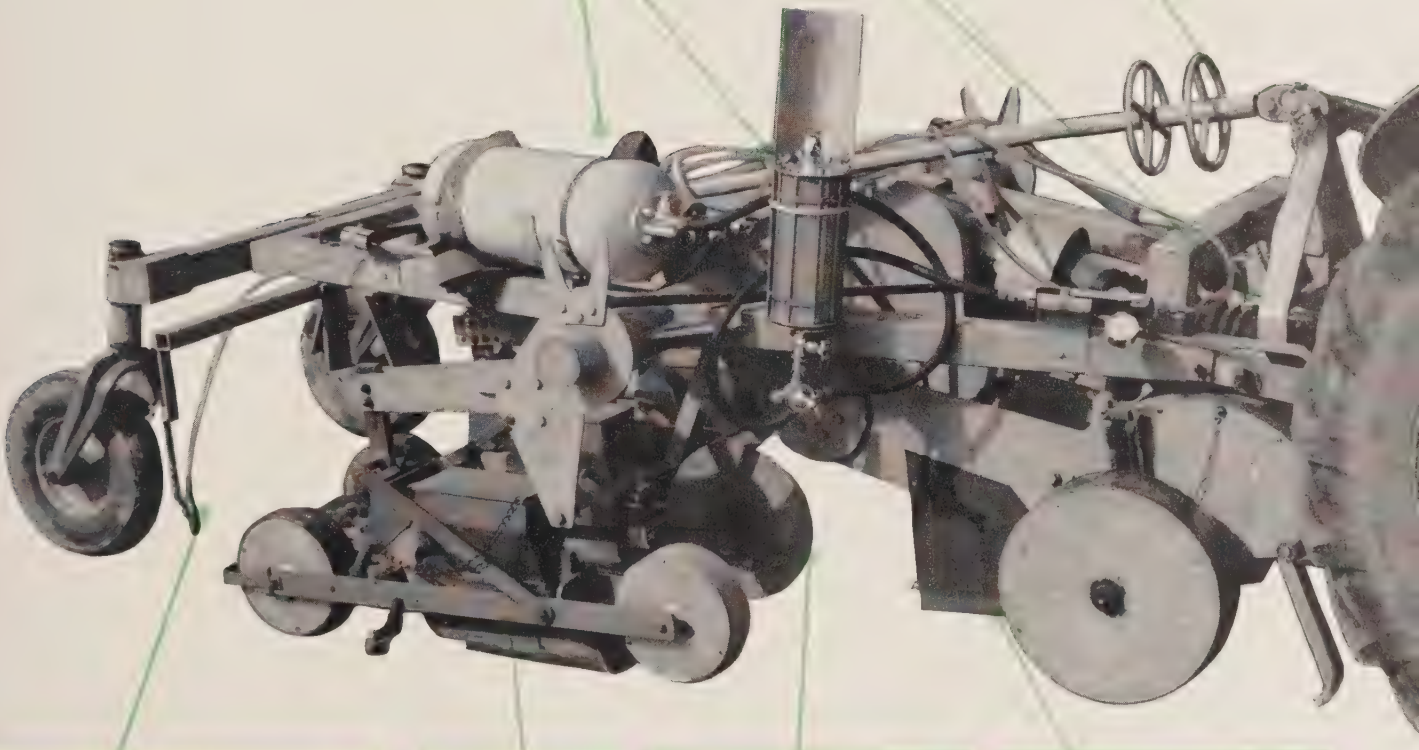
"WEED RESEARCH"— A NEW JOURNAL

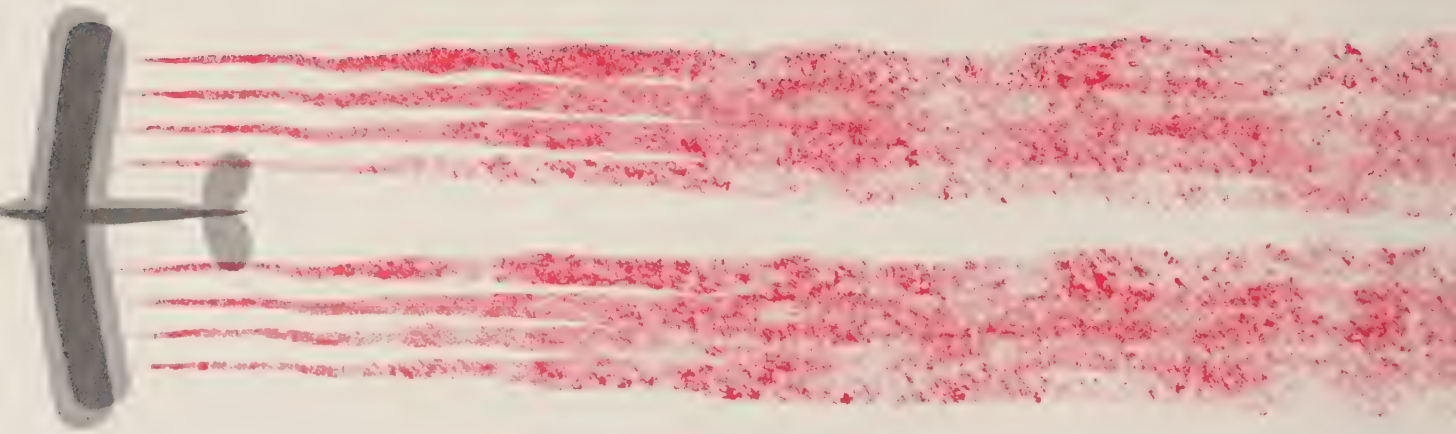
The first issue of *Weed Research*, the official journal of the European Weed Research Council (which was formed in April, 1960) was due to appear in March, 1961. The journal will publish scientific papers from all parts of the world describing original research on any aspect of the study of weeds and their control. Its scope will be wide and the main criteria for acceptance will be the intrinsic interest of the work described and a high standard of presentation. Papers which are fundamental or international in character will be particularly welcome. They may be written in the English, French or German languages.

Further information may be obtained from the editor, Mr. J. D. Fryer, Agricultural Research Council Weed Research Organisation, Kidlington, Oxford.

soil acting herbicides

A PROTOTYPE MACHINE


Oxford precision sprayer.
P.t.-o shaft.
Variable linkage to adjust pressure of drills on ground.
Spray jet positioned to apply herbicide after drilling. The pair to this jet is hidden in the picture.
Seed drill.
Modified roller to consolidate soil before drilling.
Rotary cultivator unit and depth wheel.



A Tiger Moth jettisons spray. As a safety measure, agricultural aircraft are fitted with a jettison so that in an emergency the load can be quickly dumped, enabling the machine to climb away.

Agricultural aviation

A BIRD'S EYE VIEW

by **Peter King,** *Crop Culture (Aerial) Ltd.*

Like farming with machinery of any kind, farming from an aeroplane involves a complex variety of techniques and equipment, and the problems raised by a Lincolnshire potato or a Panamanian banana may require quite different solutions from pilot, aeroplane and agronomist. I cannot claim to be able to write about the world-wide characteristics of aerial agriculture, but perhaps it would be of interest to list a few of the differences found in those parts of the world where Crop Culture operates, ranging from Central America to the Sudan and from the United Kingdom to Australia.

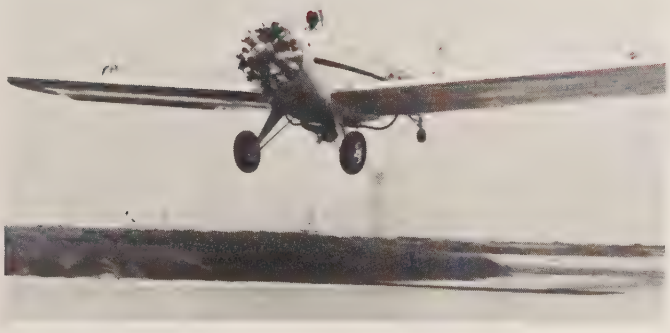
The actual business of applying chemicals from the air is relatively simple and is commonly practised by quite small organisations. The pattern of agriculture round the world is still that of the small grower and even an area dominated by one crop—cotton, for example—will often be divided into a large number of farms all requiring different treatments, so that close attention is required for the proper identification of individual fields. Such an operation is a highly organised affair requiring the closest management of pilots and ground personnel who are thoroughly familiar with the area. Personal contact between operators and farmers is essential if confidence is to be built up.

Unfortunately price-cutting wars are common in this business. Usually work must be obtained in the face of competition from other operators and prices are often cut quite indiscriminately to obtain a proportion of the work. It is easy to say that price cutting leads to poor and hasty workmanship, lower safety standards and inadequate reserves, but it is sometimes very hard to practise the converse by refusing to spray at low prices and therefore selling off surplus equipment and giving notice to experienced crews. But from time to time this course is necessary, however unpleasant it may be.

Small Firms

The United States has the largest fleet of agricultural aircraft (with the possible exception of Russia) and the characteristics of the average crop-spraying company in America may be of interest. These figures are taken from the 1959 report of the National Trades Association surveying agricultural aviation in the United States in 1958. Over half the operators who completed the survey were working

An aerial view of the base of Atomec, an associate company of Crop Culture in Ecuador.



The Snow S2A, a new aircraft designed and built specifically for agricultural work, and now in quantity production at Olney, Texas.

in their home state, with an operating radius of 30-60 miles. These firms averaged three to four aeroplanes. Less than 1 per cent. of all firms operated outside the United States. The operating season averaged 5.27 months of the year and the average United States' operator treated 46,600 acres a season.

This pattern is general almost throughout the free world. The small size of individual firms has greatly influenced the way in which the industry has built up. Companies are generally too small to have elaborate pilot training schemes, too small to have much influence individually with aircraft and equipment manufacturers, and, perhaps hardest of all, they present an easy target to the legislator. To help the industry speak with a single voice, trade associations have been formed in most countries and these can do much to help the small operator if they are sufficiently well supported by industry.

Crop Culture

In the case of my own Company, another way has been found to combat the problem of smallness. Crop Culture was formed in 1955 to spray cotton in the Sudan, and obtained a contract for about 2,000 acres (around 20 hours' flying). Two Tiger Moths were converted for spraying and fitted with long-range fuel and oil tanks for the 5,000-mile ferry flight from England; an Anson was added to the fleet to carry additional personnel and aircraft spares. Following this modest start, Crop Culture had expanded to seven aircraft by the following Sudan season, and soon negotiations were started with a French company to form a joint enterprise in the French Cameroons. Later still, local companies were formed in Central and South America jointly with nationals of the countries concerned. In 1958 a Sudanese company was also formed.

In this way a network of companies has been formed, each retaining, to a large extent, its autonomy, but with the advantages of exchanges of personnel and increased reserves of aircraft. Crop Culture and its associated companies now have some 60 aircraft operating in eight different countries.

By keeping the day-to-day management as far as possible in the hands of the men on the spot, the cost of central administration has been held to under 5 per cent. of the turnover. This gives some idea of the degree to which management is kept in the hands of the local companies.

I have mentioned that in order to remain in business an operator must be highly competitive. He is also usually operating on limited capital resources, and the industry was as a result largely built up on the use of converted surplus aircraft sold by the services. By far the largest number have come from the United States, and, because of its vast domestic market, the United States indus-

try is supplying replacement aircraft in considerable numbers.

Operating Economics

The first cost of agricultural aircraft greatly affects operating economics. Depreciation is normally reckoned over a three-year period. Engine overhaul may represent 20 per cent. of the first cost of the completed aircraft per annum, spares and overhaul another 25 per cent., and insurance is up to 20 per cent. per annum.

However, this does not mean that cheapness is everything. Reliability is equally important because a few hours' delay through a mechanical failure can throw out the tight schedules of spray work that lie ahead of the aircraft. The balance between cheapness and reliability has to be nicely judged. Above all, the aircraft must be safe.

The choice of the type of aircraft for the job is sometimes taken out of the operator's hands by events beyond his control. For example, one of our companies in the banana-growing areas of Central America recently found itself faced with an increase in application rate from one gallon an acre to 30 gallons an acre, because of a new approach to fungus control. The small Piper aircraft which had been applying one gallon had to be discarded in favour of much larger machines with tanks of greater capacity.

Helicopters

While discussing the subject of aircraft types mention should be made of the helicopter which, contrary to popular belief, comprises only a very small percentage indeed of the world's agricultural aviation fleet. In general, helicopters are more expensive to operate than fixed-wing aircraft and it is seldom that they can achieve a large enough increase in work output to justify the additional cost. However, there are occasions when they become attractive—for example, when it is difficult to locate landing strips and when small and irregularly shaped fields are to be treated.

It is perhaps worth recording two points that are not often emphasised when considering helicopters in connection with crop spraying. The first one is against them; from the slender statistics available it does not appear that their accident record is any better than fixed-wing aircraft. They seem just as liable to hit obstacles as their fixed-wing counterparts. The second is of interest for the future. The operating costs for the types of small helicopter commonly used today were quoted by N. D. Norman in a paper at the 1959 International Agricultural Aviation Conference at about £36 10s. per hour against a fixed-wing cost of £22; he quoted an output for the helicopter under British conditions of approximately 60 acres an hour, while the fixed-wing aircraft sprays approximately 40 acres an hour; this gives a difference in cost per acre of approximately 10 per cent. in favour of the fixed-wing aircraft.

The economics of using helicopters have therefore only to be improved to quite a small degree for them to equal fixed-wing aircraft, at least under United Kingdom conditions. I believe that a small simplified helicopter, perhaps with reduced payload and forward speed, could be evolved for such work. There is undoubtedly a large market in the United Kingdom and Europe generally, where fields are small, for a simple helicopter or some other form of vertical take-off machine.

At present with existing equipment, it is my view that only in exceptional circumstances can aerial agriculture be undertaken in the United Kingdom at a price which makes it attractive to the farmer. The weather and the terrain, aided by the skilful manner in which cables and powerlines have been deployed across the countryside, combine to make aerial spraying hazardous. It has been calculated that the replacement value of all the agricultural aircraft damaged during the 1960 season in Britain was about equal to the total turnover of their operators.

Insurance

This leads us to the subject of insurance. As mentioned earlier, full insurance rates can be as high as 20 per cent. The cost of other types of insurance is also high, although on the whole the industry's claims record in this respect is good. The United States' survey mentioned earlier records that only 12 per cent. of the operators recorded damage claims against them, of which about half were drift. The drift claims averaged about £300 and all were settled out of court. The rates charged for drift insurance vary widely from country to country but the majority are covered by the British insurance market.

There are other and less well-known hazards for the aerial operator. One of our pilots in Ecuador collided with a pig on landing, the animal having strayed across the landing strip at the last moment without warning. The same pilot was peppered with shot by an eccentric Englishman who disliked aeroplanes flying low over the countryside. Yet another of our pilots was stoned by irate villagers in Pakistan because the insecticide he was spraying had poisoned the fish which formed their staple diet; one stone made a sizeable hole in the cowling of his Beaver aircraft. Another pilot walked into the field on a British farm where his aircraft had been parked overnight, to find a large hole in the fuselage; on investigation this proved to contain a horseshoe, left behind by an animal which had put its foot through the side of the machine.

It follows that a phlegmatic temperament is a useful attribute for the agricultural pilot, and men who have also the necessary flying ability coupled with interest in agriculture are a rarity. There is a strong 'international' element in the pilots employed on this work—our Company has a Scotsman and a New Zealander in Jamaica, an Australian in Colombia, a Dutchman in Panama, a Frenchman in the Sudan. However, in any one country the predominant element is normally the national one, and this form of flying will, like airline work, increasingly become a domestic affair.

The overall character of this specialised form of aviation is thus a mixture of national and international flavours. Like the chemicals which are applied and the techniques employed in their application, aerial agriculture is a business which brings together pronounced national elements and a high degree of international standardisation.

Karakul sheep grazing in South-west Africa. This landscape is typical of the area.

Persian lamb from South Africa

Photos: The Thorer Fur Processing Company, Capetown.

Originating in the region around Bukhara in Southern Russia, an area famous for its rugs, the Karakul sheep, or Persian lamb, has been introduced into many countries of the world. It was in 1907 that these sheep were first imported into South-west Africa and the Union for the production of furs for coats and other garments. Since then, and particularly over the past 30 years, with the help of advances in the fields of animal husbandry, processing machinery and pesticides, and with improvement in transport and marketing, the production of Persian lamb in South Africa has developed into an industry which in 1959 was worth between £7 and £8 million per annum. This figure, which represents the sale of over 3 million skins, was about half the total sales of Persian lamb skins on the London auction markets; most of the other skins sold came from southern Russia and Afghanistan.

Many of the Karakul sheep farms in South Africa cover 200,000 acres or more. The farms are divided into sections, each section being based on a *kraal*—or corral—to which the ewes (which lamb twice a year) are gathered for daily watering and counting, and for removal of the lambs.

Apart from the everyday aspects of animal husbandry, two other aspects of production, breeding and nutrition, have to be borne in mind as both have direct influence on the type and quality of the skins.

While black is the traditional colour of Persian lamb furs, other colours are produced to meet the requirements of the constantly changing fashion in clothes. Until recently, the only way in which coloured skins could be made was by bleaching the black skins and then dying them, a process which, unless skilfully carried out, can seriously diminish the strength of the hair and consequently the lustre and life (normally about 25-35 years) of the finished garment. This problem is now being overcome, however, by breeding strains of brown and grey Karakul. To satisfy the demand for the wide range of colours in Persian lamb furs, and in order eventually to overcome the neces-

orting and inspecting skins at ne factory before processing.

The wet department. Here skins are soaked and fleshed.

Black and grey day-old Karakul lambs.

The leather is softened by hand, the process being carried out on the traditional benches seen here.

Skins in the dyeing department—one of the most important parts of the factory.

sity of bleaching, white varieties of Karakul sheep are being bred, the skins of which can subsequently be dyed to the required shade.

The highest grade skins, with thin pelt and fine hair, are produced in the arid southern region towards the Namid Desert. In areas of higher rainfall great care has to be taken to avoid over-nutrition and subsequent coarseness in the furs; in these regions the nutrition level of the sheep is commonly controlled by maintaining a careful balance between cattle and sheep populations.

Although colour and fineness of skin and hair are important, the most important factor in Persian lamb production is the type and pattern of curl which is characteristic of this fur. For this reason, detailed records are kept of all breeding ewes and rams and all lambs are examined before they join the breeding flocks. The importance of maintaining a high-quality curl is illustrated by the wide difference in price of skins in the auction market: an outstanding skin can easily fetch £5, while a skin with a poor curl pattern may realise as little as twelve shillings.

The first stage in the production of the Persian lamb skin is the slaughter of the lamb within 24 hours of birth. Skins are carefully opened up and, after washing, are spread on hessian frames to dry in well-ventilated sheds. During this processing, and in subsequent storage and transport, the skins are liable to damage by skin beetles (*Dermestes* spp.) and bacteria, which may seriously detract from their appearance and their serviceable life. Recent investigations at the Leather Industries Research Institute at Grahamstown, South Africa, have shown, however, that washing the skins in a mixture of dieldrin emulsion and a fungicide based on quaternary ammonium compounds gives adequate protection against attack without damage to the skin or hair.

Skins being dried under carefully controlled conditions.

Large rotating drums, containing sawdust and chemicals, are used to remove excess processing chemicals and to clean the skins.

efore despatch the skins are inspected and any necessary repairs carried out.

A finished Karakul coat.

The collection of the dried skins from the farmers is carried out either by private buying organisations or by large co-operatives, who also mark, bale and despatch the skins. The majority of the skins are sent to fur auctions in London where they are sorted and sold. Some are bought at the London auctions on behalf of South African buyers and are then shipped back to South Africa for processing before being made up into garments in South Africa and elsewhere.

Before the skins are processed they undergo rigorous inspection, and damaged skins are rejected. After sorting, the first stage in processing consists of soaking the skins and removing the excess fat, an operation which is carried out in what is known as the 'wet department'. Some operations are still carried out by hand. In the dressing department, for example, the skins are worked on traditional benches where, during the course of dressing, the fibre is opened up to provide a supple leather.

Dyeing is a process that calls for great skill, particularly in the case of black skins, where a long-established formula, containing only vegetable dyes, is used to give the high gloss and brilliant blue-black shade which is characteristic of the black Karakul fur produced in South Africa. A considerable number of skins are still bleached and dyed to meet the demand for brown and grey Karakul, although as has already been stated, sheep of these colours are now being bred.

In the final stages of processing the skins are dried in constant temperature and humidity chambers; next they are treated in large revolving drums containing sawdust in which excess processing chemicals are extracted and the furs cleaned; and finally they go to the despatch department where small damages are repaired before packaging and despatch to both domestic and export markets.

ACTIVITY OF INSECTICIDES ON ABSORBENT SURFACES

An important factor in malaria control

by **N. van Tiel,** Ph.D., *Woodstock Agricultural Research Centre.*

In the field of practical application of insecticides the persistence of a given toxicant on the substrate to which it is applied presents two kinds of problem. First, it is of prime concern to the entomologist who in many instances wants a high degree of control for a sufficiently long period. Secondly, it is of no less concern to the toxicologist whose task it is to ensure that no harmful residues of the chemical remain in crops or food materials obtained from crops. Finding an adequate balance between these two requirements is of major importance in agricultural applications of insecticides.

The picture is essentially different in the field of indoor residual spraying for public health purposes. A residue problem in the toxicological sense of the word does not exist here, and the chief aim is a prolonged residual effect. This article is concerned with certain problems arising in the application of residual sprays for malaria control. The basic principle of this application is relatively simple: the active material is sprayed at a certain dosage on to the interior walls of the houses; mosquitoes resting on the surface pick up a lethal dosage and are killed. At first glance this seems to be a very straightforward procedure, but in fact it represents a somewhat complicated combination of factors.

First of all there is the insecticide itself with its various characteristics (such as toxicity to mosquitoes, which determines the dosage to be applied; and volatility and stability, which determine, among other things, the persistence of the residual effect). In addition, there is the way that a particular insecticide is formulated so as to suit a special mode of application. Thus, for mosquito control one generally prefers the use of wettable powders, and here factors such as suspensibility and particle size come in. As regards suspensibility of wettable powders, official specifications have been laid down by the World Health Organisation in order to ensure that the material can be diluted easily, keeps well in suspension during the time of application, and does not block the spray nozzles. Particle size is important in this respect, but it is also important in connection with the effectiveness of the residue, as in general small particles are more toxic than large particles.

Secondly, there is the apparatus necessary to apply the product to the wall, and the technique of spraying. It is beyond the scope of this article to expand on this matter in any detail, but it may be mentioned that a considerable amount of work has been done on the development of suitable spraying equipment and on the design of nozzles, in order to ensure efficient spraying, correct dosage and, as far as possible, evenness of the deposit over the wall surface. Rate of dilution, pressure in the sprayer, distance between the nozzle and the wall have also, of course, to be borne in mind.

So far we have been dealing with factors which to a large extent, at least, are under control. However, apart from toxicant, formulation and product application, there are two other important factors to be considered, namely, the substrate and the insect which comes in contact with it. There is very little that can be done about the substrate, and even less about the insect. Nevertheless, they face us with certain problems, as for example that of insecticide-resistance.

This article deals specifically with problems related to the substrate, and in particular with the type of substrate which is usually classified as 'absorptive'. Many of the walls of native huts in Africa, Central and South America, and parts of Asia, are constructed or at least plastered with such material, which is mostly the local soil or clay.

Effect of Humidity

In 1951 it was found almost simultaneously by HADAWAY and BARLOW (10, 11) in the UK and by DOWNS, BORDAS, and NAVARRO (6, 7) in Mexico that solid particles of insecticide rapidly disappear from a mud surface by a process which is commonly referred to as 'absorption'. It involves a change in the physical state of the residue from a particulate into a non-particulate form, and apparently

Visitors from the World Health Organisation watch dieldrin wettable powder spraying during the anti-malaria trials which were carried out at Taveta-Pare, Tanganyika, on the persistence of residual insecticides on mud walls.

the insecticide molecules move along the surface into the interior of the mud. Once the particles have disappeared, the further fate of the insecticide is largely dependent on humidity. Under dry conditions the insecticide becomes strongly adsorbed on to the surface of the mud particles, and there is neither further inward migration nor uptake by insects contacting the surface, and residual toxicity is completely lost. Under humid conditions it is assumed that there is preferential adsorption of water by the mud particles and the insecticide retains its mobility. This means that there is further inward migration of the absorbed insecticide until after a certain period a state of equal distribution of the insecticide throughout the mud layer is attained. On the other hand, it also means that any given quantity present in the top layer is more available for uptake by insects, and therefore residual toxicity is retained in spite of decreased concentration (1, 2, 3, 4).

An extensive investigation into the problem of insecticide absorption, with particular reference to dieldrin, has been carried out at Woodstock Agricultural Research Centre. In this work the chief emphasis has been laid on three major points—the influence of humidity on residual toxicity and distribution of the insecticide in the mud; possible ways of reducing absorption by altering the formulation; and the factors governing the performance of insecticide wettable powders under field conditions.

Gerolt (9), in his work at Woodstock, studied the influence of humidity on toxicity and distribution of the insecticide by employing thin (0.5mm.) layers of a homogenised mud/insecticide mixture, thus excluding the factor of inward migration from a surface residue into the interior of the mud. After storage of such thin mud/dieldrin layers, applied on glass plates, at various relative humidities, *Aedes aegypti* females were exposed for various lengths of time, and the medium lethal exposure time (MLT), i.e., the time required to give a 50 per cent. mortality 24 hours after exposure, was determined for each level of humidity. The results showed a much more spectacular effect of humidity than in tests with the usual thick mud panels. In fact there appeared to be a straight inverse correlation between log. MLT and percentage relative humidity. Any increase in humidity by 10 per cent. doubled the toxicity (halved the MLT), and whereas at 90 per cent. relative humidity only 10 minutes' exposure was required for 50 per cent. mortality, about 10 hours would be necessary to obtain the same effect at 30 per cent. relative humidity. This influence of humidity on toxicity was shown to be completely reversible.

Further experiments were done in order to determine whether humidity changes would in any way influence the actual distribution of the toxicant in the mud layer, and for this purpose use was made of C^{14}-labelled DDT, homogeneously mixed with the mud.

Figure 1 shows what happened when conditions of relative humidity changed. Immediately following the

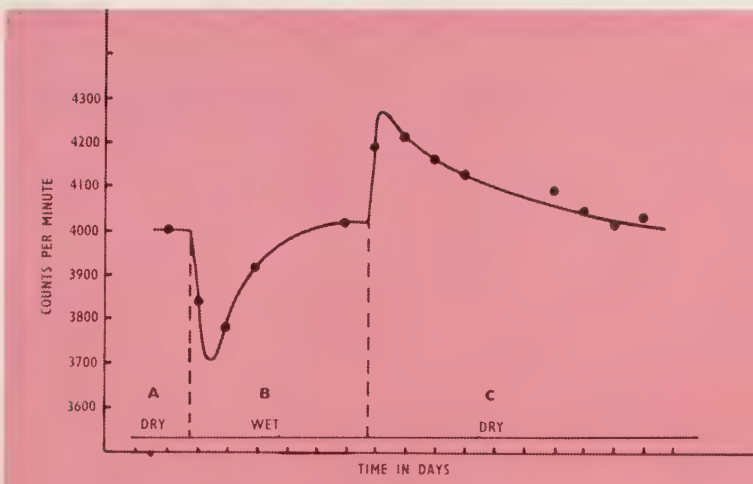


Fig. 1. The influence of a change in humidity on the concentration of DDT in the top layer of the mud.

change from very low (<5 per cent.) to very high (>90 per cent.) humidity there was a sudden decrease of the DDT concentration in the top layer, but after about four days the even distribution of the insecticide was restored again within a period of about eight days. It follows that essentially the final distribution of the DDT remained even, irrespective of the level of humidity, and that only during actual absorption or desorption of water did temporary changes in concentrations of DDT in the top layer occur. In fact the toxicant moved along with the moving water, a phenomenon which we refer to as the 'washing in' and 'washing out' effect.

An interesting point is the fact that restoring the even distribution of the DDT took about twice the time under dry conditions as it did under humid conditions. This entirely confirmed the greater mobility of the insecticide at higher humidity. The main conclusion from this experiment was that the greater toxicity at higher humidity was only based on the greater availability of the DDT in the top layer, as under these conditions the only change in concentration was a temporary decrease.

Effect of Formulation

From the results obtained so far one may conclude that the absorption phenomenon might not be a serious problem under humid conditions, but that it might well interfere with residual toxicity under dry conditions. For this reason further experiments were carried out with a view to altering the insecticide formulation in such a way that absorption could be reduced.

GEROLT (8) found this could be realised by preparing special wettable powders based on ground solidified melts of dieldrin with certain resinous or asphaltous adjuvants. Greatly extended persistence as compared with standard wettable powders was observed in panel exposure tests in the laboratory, whereby the panels had been stored under dry conditions (relative humidity <40 per cent.). Effective adjuvants were various synthetic resins, natural resins and asphaltous products. Table 1 clearly shows the difference in performance between the two products in 30-second exposure tests with *Musca domestica*. Whereas 3mg. dieldrin/sq. dm. gave 100 per cent. kill for only a short period, not exceeding one day, half that dosage of dieldrin/coumarone resin continued to give 100 per cent. kill for at least 10 months.

These encouraging findings have subsequently led to field experiments, using Gilsonite (a natural asphaltite) as the adjuvant for reasons of cheapness, availability and ease of formulation. The experiments were conducted in Tanganyika under the auspices of the Colonial Pesticides Research Unit, Arusha (5), and in Mexico under the joint auspices of the Pan American Sanitary Bureau, the Mexican Government and Distribuidora Shell de Mexico (12). The results were surprising in two ways: the standard dieldrin wettable powder appeared to be considerably more persistent than in the panel exposure tests in the laboratory, and the performance of the dieldrin/Gilsonite was not significantly different. These obvious discrepancies between laboratory and field results, although disturbing in a way, presented a most intriguing problem. It was clear that certain factors were operating in the field which had not been taken into account in the laboratory tests, and it was evident at that stage that only further detailed field trials could provide an answer.

Tests at Arusha

In view of these results the author carried out both laboratory and field experiments in cooperation with the Colonial Pesticides Research Unit at Arusha (13).

Laboratory Experiments. The first approach was a series of laboratory exposure tests, comparing the residual effect of dieldrin and dieldrin with various adjuvants, such as Gilsonite, colophony and chlorinated polyphenyl resin (Aroclor), on mud panels against *Anopheles gambiae*, the chief malaria vector in East Africa. Table 2 gives a survey of the total results, covering over 40 tests, and expressed as numbers of tests in which each dieldrin/resin product gave a lower, equal or higher mortality as compared with dieldrin alone. It was shown that neither Gilsonite nor colophony gave an improvement in persistence, and only the performance of dieldrin/Aroclor was considerably better than dieldrin alone in the majority of the tests.

These laboratory results were in agreement with the field results referred to above, but the differences in performance of dieldrin/Gilsonite in these experiments and in the early experiments at Woodstock called for further explanation. Table 3 shows the influence of test species and test method on the relative performance of dieldrin, dieldrin/Gilsonite and dieldrin/Aroclor on absorptive mud. It can be seen that in all cases dieldrin alone was rapidly absorbed and residual toxicity lost. Dieldrin/Gilsonite showed increased persistence in the panel exposure tests with *Aedes aegypti*, but the use of another test method or the use of *Anopheles gambiae* apparently altered this picture, and dieldrin/Gilsonite failed under these conditions, in contrast to dieldrin/Aroclor.

An explanation can be found when we look at the mobility of the insects during exposure. Whereas in panel exposure tests with *Aedes aegypti* the insects are mobile and the pick-up of the non-absorbed dieldrin/resin particles is facilitated, the same species prefers the resting state in the exposure chamber method (developed by the US Public Health Laboratory at Savannah), where a considerably larger area of treated surface is available to the insects, and exposure is in the dark. *Anopheles gambiae* prefers the resting state under both exposure conditions.

To summarise, there was a close agreement as regards the relative performance of dieldrin and dieldrin/Gilsonite between all laboratory and field results with insects in the resting state. Apparently not enough toxicant is picked up by the insect from dieldrin/Gilsonite under these conditions. No further investigation has been carried out on the causes of the better performance of Aroclor; it may well be that the solubility of the resinous adjuvant in the insect cuticle is one of the factors involved.

Field Experiments. The next step was to investigate whether the long persistence of dieldrin/Aroclor could be demonstrated under field conditions as well as in the

Table 1

Improved persistence of dieldrin/coumarone resin solidified melts on absorptive mud panels
(Percentage knockdown and 24-hour mortality of *Musca Domestica*)

Product	*Age of residue*	*No. of hours after exposure for 30 sec.*						
		1½	2	3	4	5	6	24
Standard dieldrin wettable powder (3mg dieldrin/sq. dm)	2 hours	91	100					100
	1 day	0	3	39	48	52	55	100
	2 days			0	9	17	37	71
	3 days		0	4	4	15	22	56
	1 week					0	2	27
	2 weeks						0	8
Dieldrin/coumarone resin melt (1.5mg dieldrin/sq. dm)	2 hours	49	85	95	100			100
	1 week	0	12	59	94	100		100
	2 weeks	17	72	97	100			100
	4 weeks	14	45	89	100			100
	10 weeks	11	22	44	78	87	98	100
	4 months	4	27	67	87	—	100	100
	7 months	0	2	—	52	57	82	100
	10 months		0	13	28	44	56	100

Table 2

Relative performance of dieldrin/resin products
(Number of tests showing lower, equal and higher mortalities as compared with dieldrin)

Product	*Mortalities compared with dieldrin*			*Total number of tests*
	lower	*equal*	*higher*	
dieldrin/Gilsonite	12×	22×	10×	44
dieldrin/colophony	11×	17×	14×	42
dieldrin/Aroclor	2×	11×	32×	45

Table 3

Relative performance of dieldrin and dieldrin/resin on absorptive mud, using different test species and test methods
(Percentage 24-hour mortalities)

Test species	*Aedes aegypti*			*Aedes aegypti*			*Anopheles gambiae*		
Test method	*Panel exposure test*			*Exposure chamber test*			*Panel exposure test*		
Exposure time	¼ *hour*			*4 hours*			*1 hour*		
Product	*d*	*d/G*	*d/A*	*d*	*d/G*	*d/A*	*d*	*d/G*	*d/A*
Age of residue									
2 hours	100	100	100	100	100	100	100	100	100
1 month	3	100	100	3	5	92	—	—	—
2 months	0	97	100	0	0	100	12	15	92
3 months	0	81	100	4	3	100	6	6	86

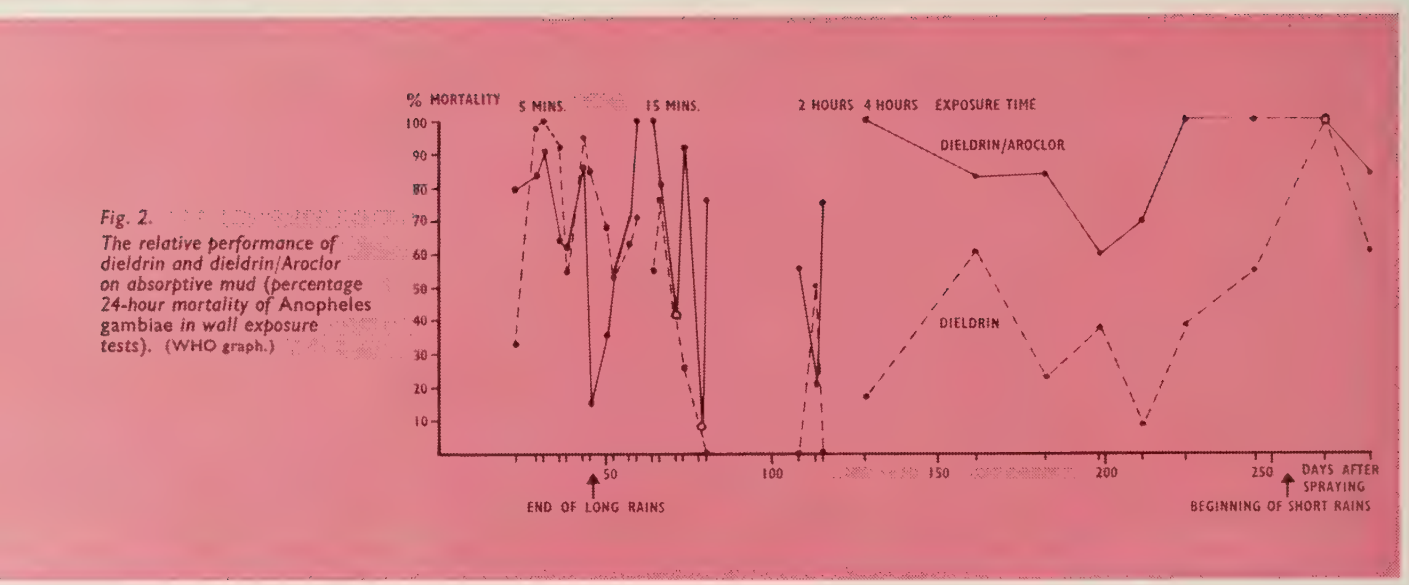


Fig. 2.
The relative performance of dieldrin and dieldrin/Aroclor on absorptive mud (percentage 24-hour mortality of Anopheles gambiae *in wall exposure tests).* (WHO graph.)

laboratory. Field work was undertaken, using the standard type of experimental huts, the inside walls of which were plastered with mud. The results of mosquito exposure tests on treated walls showed that dieldrin and dieldrin/Aroclor gave an equal performance during the rainy season, when high humidity caused a high effectiveness of absorbed dieldrin. However, with the advance of the dry season dieldrin/Aroclor showed a progressive improvement in relative performance as compared with dieldrin alone (see Figure 2). As might be expected, dieldrin/Gilsonite did not show any improvement over dieldrin alone, irrespective of the season.

An interesting feature was that, contrary to the observations with wall tests, there were no differences in overall performance between dieldrin and dieldrin/Aroclor, when assessing the mortality amongst mosquitoes naturally entering and resting in the huts for unrestricted periods. An explanation for this was found when examining the seasonal variations in average relative humidity inside the huts. It was shown that even in the driest months this average is not likely to fall below 60 per cent. for any considerable length of time. This means that although the availability of absorbed dieldrin is noticeably less than in the wet season (which causes the lower toxicity of dieldrin alone as compared with dieldrin/Aroclor in wall tests with a limited exposure time), it is still sufficient to give a high kill of mosquitoes under conditions of prolonged exposure, and thus the differences in performance between the two products disappear.

For all practical purposes we may conclude that, in the case of chlorinated hydrocarbon insecticides, absorption is a phenomenon occurring in the field, and that it can be demonstrated by biological techniques such as wall exposure tests. However, because of the favourable humidity conditions in most areas, there is not sufficient evidence to assume that it presents a major problem from the point of view of mosquito control in anti-malaria campaigns.

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Our Developing World. L. Dudley Stamp. Faber, London. 21s.

This is a second edition of the author's book, *Our Undeveloped World* which came from the same publisher in 1953 and arose from lectures given by Professor Stamp in the University of Indiana in 1950. The second edition is sufficiently different to justify the new title which, incidentally, is probably more accurate and less loaded in its implication than the original title.

The thesis of the book is the changing relationship, through time and across the world, between population numbers and national resources—particularly food, power and mineral supplies. The main emphasis is the interaction of people, land space and productivity, and the author treats this relationship on four levels—globally, nationally, regionally and locally. In doing this he presents up-to-date information on the population problem and on the agricultural productivity of the world's lands, and this is interposed with nuggets of comment and example which provide fascinating reading because of the author's ability to capture and hold the reader by his choice of facts and interesting relationships.

The treatment of the kaleidoscopic framework is, understandably, full of gaps. There is only, for example, one short chapter on minerals, two others on the consumption of food and the vast problem of population, and a short combined one on land and human resources in rural parts. The cursory treatment of large involved topics such as these would not be right in any comprehensive treatment of world land, food and human resources. The gaps are, however, permissible in a slim volume of this nature which is designed to interest, stimulate and challenge the general reader who otherwise would not read or absorb the evidence of a more comprehensive volume.

One of the least satisfactory chapters is the one dealing with the measurement of land resources and farming efficiency (Chapter VII). The measures of efficiency used are essentially physical rather than economic—yields or output per acre only being discussed rather than the ratio of output to inputs, that is, of yields to the resources used to produce them. Essentially, Kendall's ranking coefficient measures crop output per unit area and the author's own 'standard nutrition unit' is a physical measure only, though it has the advantage of bringing together in a correct proportion commodities which produce very different bulk amounts of food per acre with very different food characteristics. Land capability classes and stock carrying capacities are also physical measures of productivity in most cases.

The author defends his use of purely physical efficiency measures by stating that 'in a world short of food it is surely clear that what matters in many, perhaps most, countries is the actual amount of food produced, so, making some allowance for quality, the higher the output per unit acre the greater the efficiency of the farmer'. This statement is very debateable. The world is *not* short of food in relation to supplies being available for purchase. In fact, most of the advanced countries are busily engaged in dealing with problems of actual or potential food surpluses—e.g., USA, Canada, Australia, New Zealand, Great Britain, France, Denmark and Sweden.

Certainly, in many under-developed countries in Asia, South America and Africa and parts of S. Europe there is a need for extra food to be produced from existing land and for new land to be brought into cultivation. But in order to obtain capital and imported goods many of these agrarian countries need to export the very things they can produce easily, i.e., agricultural products. These exports, being sent to the richer countries, are meeting severe competition there from the increased home agricultural production within these developed countries. There is, therefore, in *all* countries a need for agricultural products to be made available at lower costs—with lower uses of resources like human labour and capital. In the richer countries, lower costs in agricultural production are needed *without* major increases in output. In the poorer countries, lower 'real' costs in agricultural production need to be associated *with* increases in total output. This is why any discussion of farming efficiency should sever both physical and economic measures and not just the former.

The book has, however, the great merit of quantifying the relationships between natural resources and people, so that it will be valuable as a reference book as well as providing stimulating reading. This was also true of the first edition. Despite divergence of views on farming efficiency, the book can be enthusiastically recommended for wide reading.

G. P. Wibberley.

The Economy of Latin America. F. Benham and H. A. Holley. Oxford University Press, London. 18s.

One of the dangers inherent in writing a book about Latin America is that events are apt to move more swiftly than the processes of book production so that a subsequent reviewer has an unfair advantage of hindsight over the author. I recognise the unfairness, but cannot forego the advantage!

This book is divided into two parts: a discussion by Professor Benham of the economic problems—diversification, industrialisation and the need for capital—of the region, and a largely factual account of the economies of the seven principal countries by Mr. Holley.

Its format is that of the preceding volumes in the Chatham House series of monographs on Latin America, and from this limitation stem its virtue and its deficiencies. It will go into your pocket and as a primer for one who is new to the region it compresses a surprising amount into small compass.

However, in Latin America problems of economics cannot be separated from political problems—the expansion of agriculture must be considered with land reform, and capitalisation for economic expansion with fiscal reform and the elimination of budget deficits. The symptoms of the problems (common almost throughout the region) are well set forth and Professor Benham leaves a lasting impression of the difficulties of inflation, low agricultural productivity and too much dependence upon one or two export crops. But his analysis covers only the period up to 1957 and he concludes that the outlook is encouraging provided that inflation can be tackled, and modern methods can

raise agricultural productivity. If this book had been written two years later I wonder if he would have been so sanguine? For since 1958 the terms of trade have continued to swing unfavourably for Latin America and the *per capita* product at best increases sluggishly. Surely experience through the recent and shortlived United States boom has shown that price weaknesses for major commodities are likely to persist and offset increase in volume which higher productivity can bring?

Higher labour productivity in agriculture is essential, but so is capital formation to create alternative sources of employment, or the reduction of manpower on the land creates the social problem of urban unemployment.

One could have wished that the scope of the book had permitted Professor Benham to follow his purely economic analysis by one of the crying need for structural change in the body politic as well as the body economic of many Latin American countries. Beyond agricultural productivity must be a series of industrial revolutions.

If I have devoted most of my review to Professor Benham's part of the book it is because his dialectic is more controversial than Mr. Holley's factual survey. But I cannot resist the temptation of using my hindsight to quote two examples of the danger of prophecy. Thus Holley: 'Venezuela . . . appears likely to remain in a privileged position in the countries of Latin America'; and Benham: 'The possibility of exporting natural gas by sea in liquefied form is still remote'. The latter is today a practical fact and Venezuela's economic difficulties are notorious—but all the same, buy this book, and keep it in your reference shelf—or in your briefcase. J. D. RITCHIE.

Modern Insecticides and World Food Production. F. A. GUNTHER and L. R. JEPPSON. Chapman and Hall, London. 50s.

The preface to this book states that it is not written for specialists in the fields of economic entomology and the chemistry of insecticides. It goes on to state that it will 'serve as a field-review text for classes interested in developing perspectives in the practical applications—and pitfalls of civilisation—attendant upon the exploiting of almost any biological science'.

The objective is then said to be the encouragement of interest, tolerance and understanding of the whys and wherefores of modern insecticides and acaricides, problems of their use and problems from their use.

The impression given is that the authors feel that there is a great deal of ignorance and intolerance of the use of insecticides and acaricides and that their book will help to remedy this situation. It is difficult to believe that this book, which is technical even if it is not highly technical, will be sufficiently widely read by non-specialists to have much effect on any prevailing misconceptions.

The title of the book could convey the idea that it was mainly concerned with providing data on the quantities of food saved by modern insecticides and acaricides from destruction by insects and mites, and the part that chemicals now play in allowing crops that could not otherwise be grown, to be grown. But this is not so.

The book first gives an outline of general entomology and acarology dealing with the paleontological, morphological, biological and ecological aspects; there is in this chapter a short section on the losses caused by insects and mites. Further general information on mites is given in Chapter 8. There is then a chapter on methods of control, which includes chemical and other control methods. The third chapter deals with the evolution of modern insecticides, the problems arising from their intensive use and the future prospects of chemical control. This chapter also includes a section on losses caused by insects and the savings gained by the use of insecticides. Chapter 4 discusses the factors influencing the effectiveness of insecticides. Chapter 7 is concerned with the problem of the production of strains of insect resistant to insecticides, and Chapter 8 with mites and acaricides.

The rest of the book, consisting of Chapters 5, 6, 9, 10, 11, 12, 13, 14, 15 and 16, gives an account of different groups of chemicals used to control insects, mites and nematodes as sprays, dusts, fumigants and attractants and repellents; their properties, formulation and methods of use, and the problems arising from their use.

There is an excellent chapter defining the problem of residues toxic to man and describing how it is being dealt with; but although it is implied, more direct emphasis might have been laid on the need for chemicals specifically active on the pest and relatively non-toxic to man.

The resistance problem is also described comparatively briefly and the outlook for the future of pesticides is stated to be gloomy on this account; however this pessimism may be because the possible ways in which the problem may be overcome in the future are not sufficiently recognised.

The authors appear to have taken considerable trouble to present their information, and there is a great deal of information presented in this book, in an easily readable and readily assimilable form. It should prove most useful in providing the student and worker in the fields of applied entomology, acarology and nematology who are not specialising in chemical control, with an up-to-date account of the use of chemicals in these fields. C. POTTER.

The Mango. L. B. SINGH. Leonard Hill, London. 84s.

Research on the mango is so incomplete that, although Dr. Singh has diligently recorded all that is known on the subject, the information still appears inadequate. It is for this reason that one has a sense of disappointment with the book, for which the author is only partly responsible. As a scientist, he is fully aware of this deficiency, for his book abounds in such phrases as 'studies yet to be made'; 'lack of systematic investigations'; 'knowledge still imperfect and inadequate'; 'no reliable information acceptable to science'. Numerous writers have recorded observations and views, and the bibliography is impressive in length, but some of these views appear to be unsupported by scientific evidence.

Despite the pre-eminence of India in mango production—there are said to be over two million acres planted to the crop in that country—it would seem that there is a great difference between the principles of mango culture and its practice in India. One is told, for instance, that many mango orchards have grown into jungle through neglect, and that nurserymen often collect seeds haphazardly from the wayside or from city refuse to obtain stocks for grafting. Presumably for such reasons as these, Dr. Singh confines himself almost entirely to recording the scientific aspects of the subject rather than to detailing the cultural practices in India. This is regrettable, for one would have hoped to profit by the practical experience gained in the country which produces the finest mangoes in the world.

The author makes his most valuable contribution to science in the chapters on botany, cytogenetics and breeding, fruit-bud differentiation and productivity in cropping, where he summarises the fruits of research work in India and elsewhere which must form the basis for improvements in varieties and cultivation. In the following chapter—perhaps the most successful in the book—he succeeds in dispelling the confusion which has

always existed regarding varietal names and classification of varieties.

The chapter on nutrition sums up present knowledge. The author states that the study of fertilising the mango is still in its infancy and more thorough research is necessary before definite conclusions can be drawn. Chapters on diseases, pests and parasites cover the subjects adequately and are accompanied by excellent illustrations.

Dr. Singh is less successful in writing on propagation; the chapter is unnecessarily long and contains a mass of information more suited to an elementary book on the subject. One also feels that in the final chapters, on marketing and utilisation, he is on uncertain ground: he frequently emphasises the obvious, is often repetitive and sometimes arrives at rather loose conclusions.

In this volume clarity is frequently impaired by faulty syntax, which does not make for easy reading. Nevertheless, the publication is opportune since research on the mango is receiving a much larger share than hitherto of State assistance and patronage in India. The book is well produced and the numerous excellent plates are well chosen. D. H. GRIST.

The Pineapple. J. L. COLLINS. Leonard Hill, London. 60s.

This book is divided into three sections: Botany (127 pages), Cultivation (93 pages) and Utilisation (46 pages), all well illustrated with photographs and drawings; and at the end are a bibliography and indexes. The first section deals with the history of the pineapple as a cultivated plant; the taxonomy and ecology of related wild species in South America; the structure and anatomy of the various parts of a pineapple plant; the principal varieties in cultivation; cytology; genetics; and the breeding of new varieties.

The section on cultivation deals first with general questions of climate and soil, and then with cultural methods in most of the countries where pineapples are now grown; then follow chapters on pests and diseases and on the influence of varying climatic factors on development. The final section has chapters on fruit preservation and uses, by-products (including fibre from leaves) and future prospects of the industry. The book thus gives a comprehensive survey of its subject, which is covered by no other recent publication.

The author was for many years geneticist at the Pineapple Research Institute, Honolulu, and has been in close touch with all aspects of the recent development of the pineapple industry. He also made considerable travels in South America in the search for wild relatives of the pineapple (some of which were later used in breeding) and the information so obtained resulted in a fuller understanding of both taxonomy and ecology of this group of plants. As is natural, more attention is devoted to all aspects of the pineapple industry in Hawaii than elsewhere; but as Hawaii produced in 1955 (the last year for which records are given) some 70 per cent. of the world's canned pineapples, and has been a leader in research and in cultivation techniques, this does not result in an unbalanced treatment.

Malaya, however, receives something less than justice, in view of the fact that 20 years ago Malaya was the world's second producer. The author does not refer to the considerable information about the history of pineapples in Malaya contained in Burkhill's *Dictionary of the Economic Products of the Malay Peninsula* (1935) nor does he refer to any article in the *Malayan Agricultural Journal* later than 1928. He mentions the varieties Sarawak and Mauritius as cultivated in Malaya, but does not indicate that Sarawak is a local name for Cayenne and that Mauritius is a form of the Queen pine.

On the history of the pineapple in Europe, Dr. Collins quotes Loudon (mis-spelled consistently as London) but does not mention Philip Miller's *Gardener's Dictionary*, the many editions of which, from 1724 onwards, give much information on the subject, including descriptions of varieties. It is interesting to reflect that a century ago a pinery was a not uncommon feature of country gentlemen's establishments in England, as indicated by frequent references in the *Gardener's Chronicle* of that period. Dr. Collins mentions distribution of the Cayenne pineapple to many countries from England in the years following 1850, but does not mention Kew as the principal distributing agent, nor the fact that this variety is still known as the Kew pine in some places.

One of the problems of pineapple canning is due to the fact that the multiple fruit ripens first at the bottom, and bottom slices differ in colour and quality from those near the top of the fruit. The upper fruitlets are also smaller than the lower, so that the whole fruit is not an even cylinder. Plant breeders are trying to develop new varieties which will overcome these defects. Dr. Collins suggests that a more uniform development of the fruit might also be obtained by the use of plant hormones, which are already used to induce simultaneous flowering and can be used to delay ripening and increase the size of fruits. Research of many kinds, and its application, in many parts of the world, has been responsible for the present development of the pineapple industry. Dr. Collins' book, by summarising what has been achieved, should also provide a stimulus to further thought and action. R. E. HOLTTUM.

Better Grassland Sward. ANDRÉ VOISIN. Crosby Lockwood, London. 42s.

André Voisin writes with his usual vigour and clarity. One of his prime objectives is to show that permanent pasture is of a greater value than the ley. He does not deny the value of leys of short duration in rotation schemes, but he directs his arguments against the concept which implies that the way to improve permanent pastures is to plough them and reseed. Voisin indicates how newly sown swards may produce a very high yield of forage during the first two years followed by a decline in production—'the years of depression'; this depression may persist for five or many more years. He explains such happenings by attributing the high initial production to the rapid oxidation of soil or organic matter reserves incurred as a result of ploughing; until these reserves are refurbished, microbiological activity languishes and this accounts for the years of depression. Voisin carefully culls the literature to support his arguments.

The author places the greatest emphasis on a dynamic conception of pasture ecology and resolves various sward effects in terms of the grazing animal and its excrement, the effects of light, moisture, soil acidity and fertiliser application. He indicates how a judicious phosphate and potash application may improve pasture quality and, though he deals with the effect of nitrogenous fertilisers at some length, his conclusions, owing to the lack of unanimity in the literature, are not so well defined. He agrees that nitrogenous fertiliser application may depress white clover growth but shows how many other factors may influence this response. He quotes New Zealand evidence to show that nitrogenous fertilisers applied in the presence of large dressings of sulphur may even improve the proportion of clover in the sward.

Unfortunately Voisin does not mention the results obtained by F. C. Crofts at the University of Sydney. Crofts' pioneering work has also shown how a clear understanding of grassland ecology allied to the use of irrigation and intensive fertiliser

application may lead to outstanding forage production as measured in terms of milk gallonage.

A brief mention is made of the difficulties resulting from the application of chemical weedkillers to grassland; the problem is much more complicated in the case of grass than of arable crops. Voisin underlines the foolishness of regarding dandelions and plantains as weeds when they are known to be relished by cows.

Voisin can be faulted in that, for example, he completely ignores the tropical grasslands and the role of temperature in governing specie appearance and dominance. But all in all, the book presents a mass of information in a light, easily digestible manner. E. W. BOLLE-JONES.

Animal Husbandry Heresies. ALLAN FRASER. Crosby Lockwood, London. 16s.

The orthodoxies which the experts impose upon the rest of us, sometimes against our own better judgment, are the main target of Dr. Allan Fraser, in a book which gave him obvious pleasure to write. In the field of animal husbandry they are many and contradictory, ranging all the way from the mystical excellencies of pedigree to the mathematical reasoning of the geneticists.

The geneticists are Dr. Fraser's favourite scientific target, largely, one suspects, because they attribute to heredity only what he would put down to environment. His definition of this is a wide one, embracing not only the early life and management of the animal but also its pre-natal circumstances and even the management of the parents, especially the dam.

The nutritionists are not spared, for the generalisations they have built up on the backs of Kellner's bullocks. The rationing of livestock for production and health, the author considers, calls for more than the mere simple arithmetic of the current tables and may need its Einstein to work out its general theory of relativity.

The comparative success of peasant livestock husbandry is the subject of an interesting analysis. The peasant, Dr. Fraser points out, tends to become the servant of his stock. 'Since, fundamentally, animal husbandry amounts to a symbiotic relationship between farm animals and man, it may well be the closer the relationship, the more successful the results'. As an example he cites the way shepherds of the Middle East lead and handle their flocks.

In Britain, as in most of the developed countries of the world, animal husbandry is in transition along with the rest of the agricultural economy. The trend towards intensification has so far favoured the fowl, the pig and the dairy cow. It may well be that if things continue as they are beef will become a by-product of the dairy, and sheep return to the hills from which they originally came.

The mechanisation of animal husbandry, the author concludes, will be forced upon us whether we like it or not; the consequences may be interesting. 'Since uniformity, vitality and resistance to disease are three of the most important qualities desirable in animals subjected to factory conditions of intensive production, cross-breds may prove, eventually, to be most suitable for that specialised purpose. The pure breeding and rearing section of the industry might, perhaps, be better conducted on more conventional and established lines at least until the final results of full mechanisation have been more fully tested and are better understood'.

The last problem at which Dr. Fraser glances, from the standpoint of a medical as well as an agricultural training, is the quality of the product for human nutrition. Were this 'rather than farmers' balance sheets or trade agreements the principle directing agricultural policy . . . certain products of animal husbandry would come to be regarded as of special importance'. These are the protective foods and it is essential that they should remain protective. LEONARD AMEY.

Farm Animals in Health and Disease. (2ND EDITION). W. R. WOOLDRIDGE. Crosby Lockwood, London. 35s.

A second and revised edition of Dr. W. R. Wooldridge's *Farm Animals in Health and Disease* is now available. For those not familiar with the first edition, I should explain that it sets out—as the title implies—to present a picture of the healthy animal as well as of the diseased. What is the norm? 'The farmer', Dr. Wooldridge points out, 'may accept somewhat emaciated animals as normal, simply because his own experience has been largely limited to such animals.' How true that is of many parts of the world, the tropics and sub-tropics, especially.

In North America to-day there is a regrettable tendency to rely upon the advertising circulars and products of the druggists, both for 'diagnosis' and treatment—a short-sighted and, in the long-run, expensive way of tackling disease problems. This book should act as a corrective, in persuading the farmer to adopt a more intelligent approach. 'It is far more important to prevent or avoid ill health than to cure it', says the author. 'To do this, a full understanding of management in all its aspects is essential'. Again, 'A few years ago the germ theory of the cause of disease was held by many scientists almost as a religion, but today it is rightly appreciated that many other factors often come into play before even a specific pathogenic organism will produce disease'.

There is a chapter on Good Health, with the essentials of digestion simply explained; while the chapter on Ill Health covers parasites, mineral and vitamin deficiencies and explains how, if the gut bacteria are killed by sulpha drugs or antibiotics, the animal's natural supply of a vitamin may fail.

Other chapters in Part I deal with the incidence of disease in the United Kingdom, with control measures, legislation, and the financial losses involved. One or two examples are given of successful eradication campaigns in the USA, and parts of Africa, but the book is concerned primarily with Britain.

Part II, which runs to 350 pages, consists of chapters dealing with the diseases of cattle, sheep, pigs, horses, poultry, and rabbits, respectively. An explanation is given of each disease; and there is mention of cause, symptoms, preventive methods and means of treatment. The reader is given an insight into any given disease, but the book is obviously not intended as an aid to 'home doctoring'. There are explanations but not dosages or working directions for treatment; indeed, the inclusion of such material would have been contrary to the spirit of the book.

Those living in the tropics will find this work a valuable introduction to health and disease problems, but must look elsewhere for information about purely tropical diseases.

The book is set in a clear, easy-to-read type and is well illustrated with some excellent photographs, line drawings and diagrams. G. P. WEST.

Report of the First International Agricultural Aviation Conference. International Agricultural Aviation Centre, The Hague. £2 10s. or $7.

This excellently produced 429-page report contains a full account of the 1959 Conference proceedings. The multitude of subjects discussed in the 50 lectures delivered indicate the diverse nature of modern agricultural aviation and emphasise the tremendous range of problems likely to concern the agricultural engineer, operator, farmer or chemical manufacturer interested in this subject.

Tomato [tŏmā'to (Eng), tŏmēi'to (US)]: from Sp. *tomate* adapted from Mexican *tomatl*. *Lycopersicum esculentum* (family *Solanaceae*). 1. A native of S. America, introduced to Europe in early 16th c. and to USA in early 19th c. 2. Botanically a fruit but popularly considered as a vegetable. Excellent source of vit. A & C. 3. Often affected by nematode infestation causing stunted, wilted plants, inferior yields and loss of profits. 4. Crop should be protected from such damage by thorough treatment of the soil with D-D before planting. 5. Against this and other pests, Shell pesticides (*cf.* aldrin, dieldrin, endrin, Phosdrin and Nemagon) offer sure protection.

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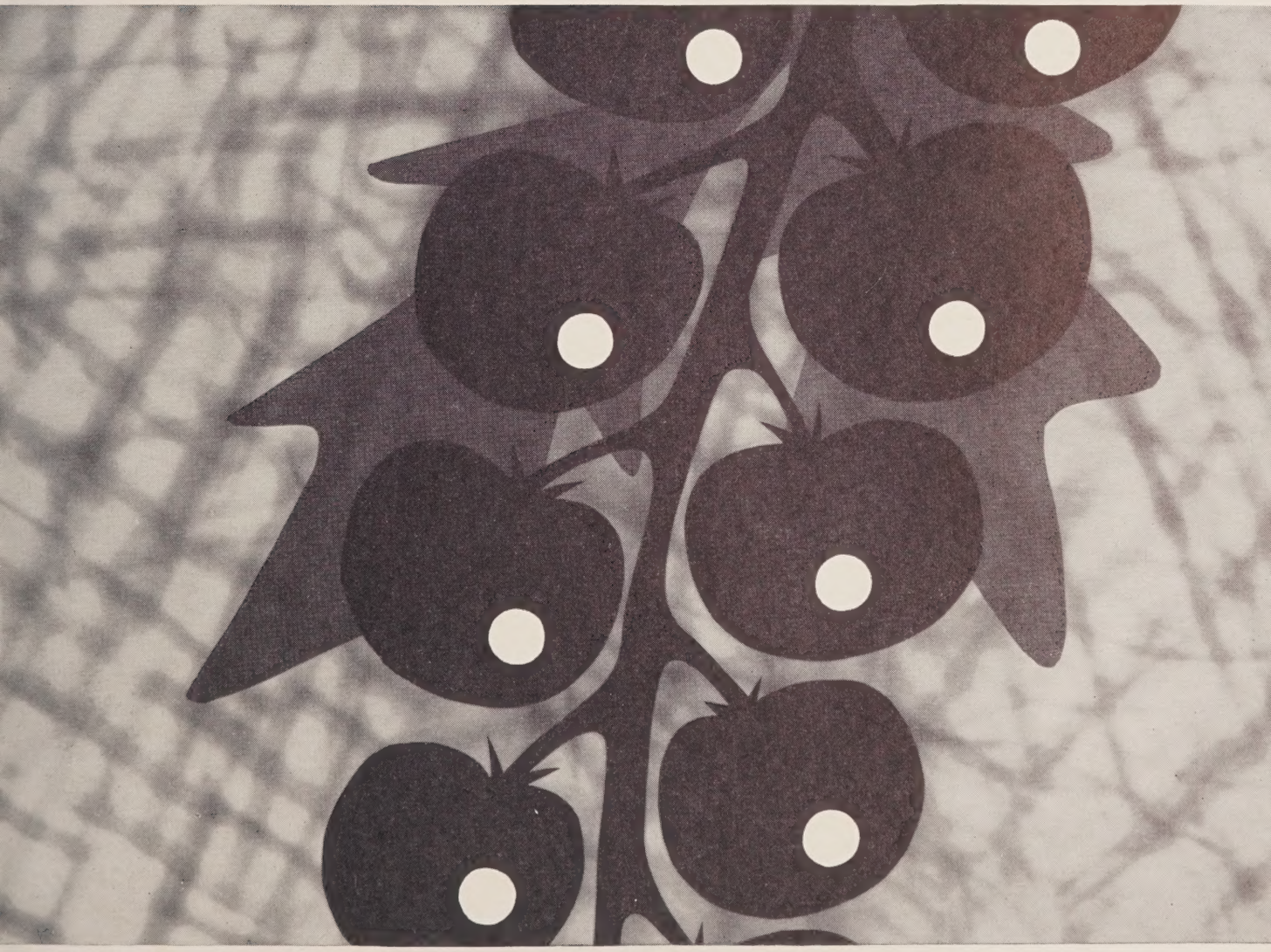

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